ENVIRONMENTALLY FRIENDLY AIDS TO NAVIGATION BUOY MOORINGS

by

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EXECUTIVE SUMMARY

The United States Coast Guard (USCG) is responsible for establishing and maintaining fixed and floating aids to navigation (ATON) in U.S. waters to facilitate the safe navigation of naval and commercial vessel traffic. These ATON negatively impact Endangered Species Act (ESA) listed threatened seagrass and coral species and their critical habitats.

A recent (2013) National Oceanic and Atmospheric Administration National Marine Fisheries Service Biological Opinion reviewed the impact of USCG ATON operations in Florida and the Caribbean on the threatened seagrass and coral species. The biological opinion concluded that USCG ATON operations negatively impact the threatened species but that the impacts are not detrimental to the survival of the species.

Since the release of the Biological Opinion, 20 additional coral species in the Caribbean and Indo-Pacific were listed as threatened under the ESA. More coral species will likely be listed under the ESA in the coming years as corals come under increasing threats from climate change and human activities.

Fixed ATON are daybeacons, lights, and ranges anchored to the seafloor with wood, steel, or concrete piles; floating ATON are buoys. Benthic impacts from fixed ATON result from the surface area of the bottom of the piles used to anchor them to the seafloor and from the spuds that USCG construction tender vessels lower into the seafloor for stabilization during pile driving and maintenance operations. Benthic impacts from floating ATON are caused by the concrete block anchor and the excesses length of chain (typically three times longer than the depth of water where the floating ATON is moored) that lays on the seafloor. That excess chain provides catenary that dampens the dynamic forces on the floating ATON mooring, which is critical for preventing the mooring from parting. However, environmental forcing of the buoy on the water's surface can drag the excess chain in a radius around the concrete block anchor. That scouring of the seafloor within the impact area radius damages or kills seagrasses and corals living there.

A Geographic Information Systems (GIS) analysis was conducted to quantify the potential benthic impact areas associated with fixed and floating USCG ATON in critical habitats of the threatened seagrass and coral species. The analysis found that thousands of times greater area is impacted by floating compared to fixed ATON. Combined, fixed and floating ATON impacted the following worst-case areas and percentages of these critical habitats:

- Threatened seagrass habitat – 1.54×10^{-2}Ha (total habitat percentage of 0.000211%)
- Threatened coral habitat – 55.69Ha (total habitat percentage of 0.00454%)
- Coral Reefs – 8.92Ha (total habitat percentage of 0.00189%)

The lost ecosystems services values associated with those impacts were estimated to be $460/year in critical seagrass habitat and $43,000/year in critical coral habitats. The estimated restoration costs total $7,300 for critical seagrass habitat and $4.8 million in critical coral habitats.

As a responsible steward of the environment, the USCG should explore options for eliminating or decreasing benthic impact areas from fixed and floating ATON in critical seagrass and coral habitats. Recommended actions include:

- Replace the one floating ATON found in critical seagrass habitat with a fixed ATON or an environmentally friendly ATON mooring.
- Minimize the number of USCG construction tender vessel spudding events when installing and maintaining fixed ATON.

- Replace floating ATON moorings in critical coral habitat with environmentally friendly buoy moorings.
- Consider becoming impact neutral by supporting seagrass and coral reef conservation or recovery projects equal in area to the areas impacted by USCG ATON.

Of all the recommend actions, installing environmentally friendly moorings on floating ATON in critical habitats would result in the greatest reduction to benthic impact areas. Environmentally friendly moorings achieve this reduction by reducing the size of the mooring anchor and keeping the mooring rode off of the seafloor. Several commercially available environmentally friendly mooring anchors and rode systems are capable of holding the largest USCG floating ATON found in the critical seagrass and coral habitats. The environmentally friendly mooring options should perform well in protected areas with fairly calm sea conditions; however, their effectiveness is questionable in exposed, open-ocean sea conditions where some USCG ATON are moored.

The cost of an environmentally friendly mooring anchor is similar to the cost of a traditional concrete block anchor; but environmentally friendly mooring rodes are more costly (around 60% greater in one particular application) than the cost of traditional chain catenary moorings. Installation and maintenance costs may be greater for environmentally friendly moorings because their installation and maintenance are best performed by divers, which represent an additional cost over typical shipboard ATON operations. The recommended annual maintenance interval for environmentally friendly moorings will also likely result in higher costs over traditional ATONs' triennial maintenance schedule.

The USCG should conduct an engineering analysis of commercially available environmentally friendly mooring systems to determine their suitability for mooring USCG ATON across their range of exposure to environmental forces. Environmentally friendly ATON moorings would also have to be engineered specifically for each ATON's unique buoy type, bottom type, tidal range, and environmental conditions.

The USCG recently (November 2014) started a Research and Development Center project on environmentally friendly floating ATON moorings. The project demonstrates the USCG's commitment to environmental conservation through the elimination or reduction of negative environmental impacts. The project's established timelines, planned prototype testing, and required reports are firm and promising steps toward the operational deployment of these systems by the year 2019.

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Environmentally Friendly Aids to Navigation Buoy Moorings

Introduction

Aids to navigation (ATON) established and maintained by the United States Coast Guard (USCG) negatively impact coral and a seagrass species listed as threatened under the Endangered Species Act (ESA) ("50 C.F.R. 223.102 - Enumeration of threatened marine and anadromous species," 2014). These negative impacts are caused by physical contact between the threatened species or the benthic environment surrounding them and the ATON itself, the ATON's mooring, or the temporary anchoring/mooring devices employed by the USCG vessels installing and maintaining the ATON. These interactions constitute a "take" under the ESA and are detrimental to the health and vitality of those species ("16. U.S.C. 1532 - Definitions," 1973).

Despite 50 C.F.R. 226 (2010) exempting areas occupied by existing federally authorized ATON and maintained channels from threatened/endangered critical habitat designation, as a responsible steward of the environment, the USCG should explore practicable new ATON mooring technologies and installation and maintenance procedures that eliminate or lessen negative impacts on the threatened coral and seagrass species; and should consider becoming impact neutral by supporting seagrass and coral reef conservation or recovery projects equal in area to the benthic areas impacted by USCG ATON.

Figure 1: Picture of USCGC OAK (Barnes, 2013)

The need for new approaches was highlighted by recent (2013) impacts to the operations of U.S. Coast Guard Cutter (USCGC) OAK (WLB-211). The OAK (figure 1) is a 225-foot sea-going buoy tender with primary servicing responsibility for 251 ATON along the coasts of South Carolina, Georgia, Florida, Puerto Rico, Guantanamo Bay (Cuba), Haiti, and the U.S. Virgin Islands ("OAK Missions," 2013). OAK's servicing and maintenance of ATON was halted while awaiting the release of a National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Biological Opinion concerning ATON maintenance within the habitats of the threatened species ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). After the Biological Opinion was released, the OAK resumed ATON operations pursuant to compliance with best management practices identified in the Biological Opinion to prevent takes of the threatened species.

This paper focuses on USCG ATON impacts to threatened seagrass and coral species and includes: a characterization and quantification of USCG ATON impact areas in critical seagrass and coral habitats; and an analysis of novel (to the USCG) and more environmentally-friendly commercial-off-the-shelf anchoring and mooring systems suitable for USCG ATON, including an analysis of their installation and maintenance requirements and a cost comparison between them and traditional ATON anchoring and mooring systems.

Background

Aids to Navigation Overview

The USCG is responsible for establishing and maintaining aids to navigation (ATON) that promote the safety of military and maritime commerce vessel navigation in U.S. waters and waters of the U.S.'s territories and possessions ("14 U.S.C. 81 - Aids to Navigation Authorized," 2012). Figure 2 provides an overview of the types and nomenclature of U.S. ATON and figure 3 demonstrates their use in a maritime waterway, in this case, Bahia de San Juan, Puerto Rico. The chart shows that ATON mark shoals and delineate safe navigation channels.

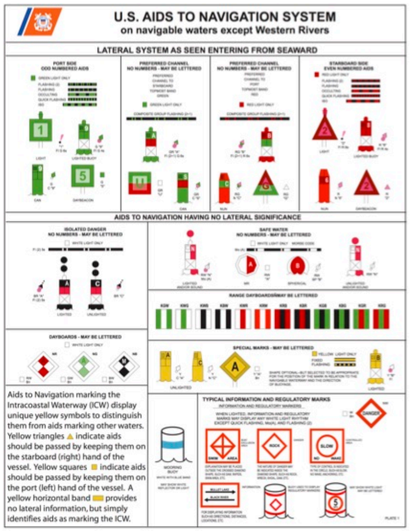

Figure 2: U.S. ATON Types and Nomenclature ("Color Aids to Navigation Insert," 2015)

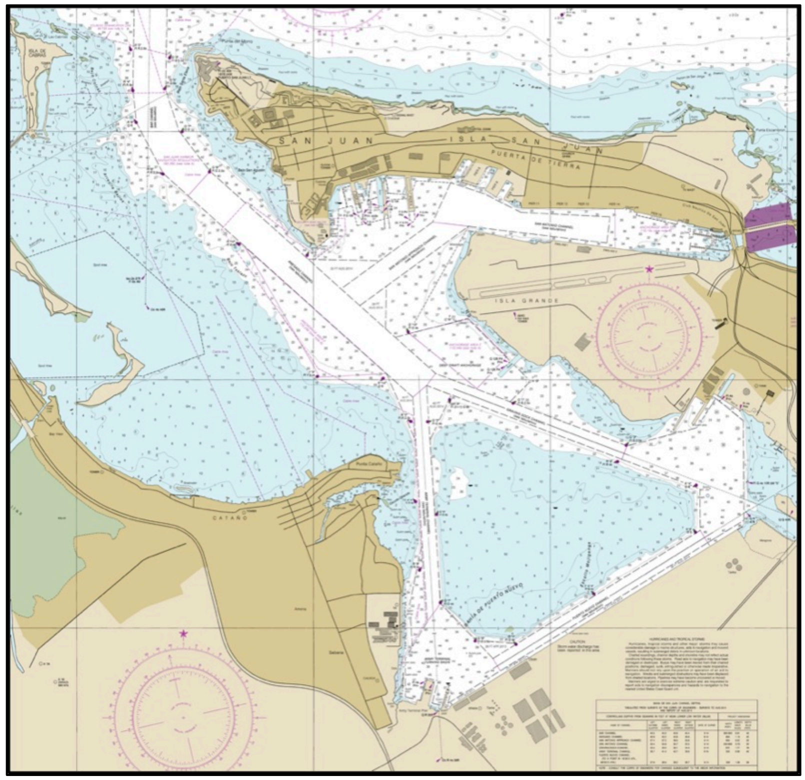

Figure 3: NOAA Chart 25670 Bahia de San Juan ("Chart 25670 Bahia de San Juan," 2014)

ATON are either fixed or floating. Fixed aids consist of one or more wooden, steel, or concrete piles driven into the seafloor that hold navigational dayboards and lights. Figure 4 is a drawing of lighted and unlighted single and multiple pile fixed aids. Fixed aids are installed by USCG construction tender vessels that extend spuds down to the seafloor for stabilization while driving the piles (*Aids to Navigation Manual - Structures, COMDTINST M16500.25A*, 2005).

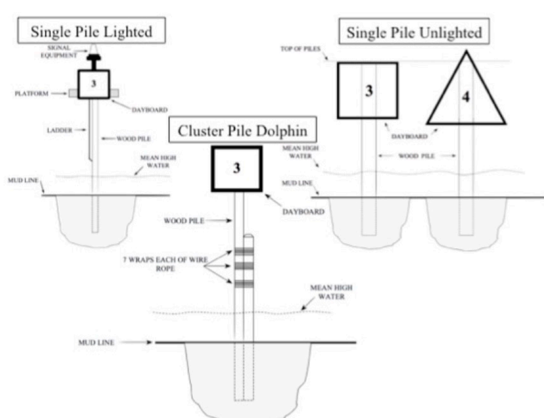

Figure 4: USCG Fixed ATON (*Aids to Navigation Manual - Structures,*

Figure 5: USCG Construction Tender With Spuds Retracted (Atkeson, 2009)

See figure 5 for a picture of a USCG construction tender with its spuds retracted (up). Fixed aids are typically used in shallow water (less than 20 feet deep) because of the limited length of construction tender vessel stabilizing spuds (*Aids to Navigation Manual - Structures, COMDTINST M16500.25A*, 2005).

USCG floating ATON are buoys with varied shapes, colors, and signaling equipment [lights, bells, whistles, gongs, radar responders (RACON), etc.] that provide navigation information to mariners (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). Floating ATON moorings (figure 6) used by the USCG are referred to as chain catenary or swing-type moorings (Demers, Davis, & Knott, 2013; Paul, Irish, Gobat, & Grosenbaugh, 1999). The floating ATON mooring consists of a sinker, typically a concrete block, and a length of chain greater than the water depth (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The length of chain used for a given ATON mooring is that which best marks the waterway or hazard while providing sufficient catenary to account for environmental changes (tides, waves, storm surges, etc.) and to damped dynamic forces (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The USCG developed the Computer-Aided Mooring Selection Guide (MOORSEL) program that incorporates 10-year greatest wind and wave information to provide a recommended floating ATON mooring configuration (including chain length) for a given buoy type and position; however, a general rule of thumb for the length of chain used is three times the depth of water (McEvoy, 2015; Merrill, 2015).

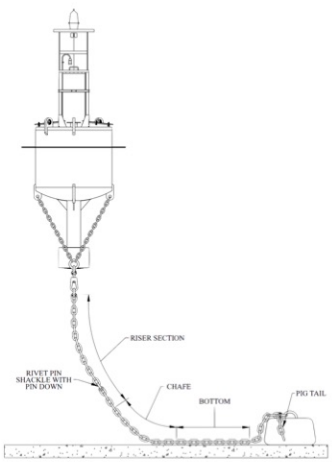

Figure 6: Typical Floating ATON Mooring (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010)

Overview of Threatened Coral and Seagrass Species

The coral and seagrass species negatively impacted by USCG ATON are listed as threatened under the ESA because they are likely to become endangered ("50 C.F.R. 424 - Listing endangered and threatened species and designating critical habitat," 2009).

The threatened coral species are listed in table 1 along with their known, general geographic distributions. *Acropora palmata* (elkhorn coral) *and Acropora cervicornis* (staghorn coral) were listed in 2006 and the remaining 20 coral species were listed in 2014. *Halophila johnsonii* (Johnson's seagrass) was listed as threatened in 1998 and is found on the eastern coast of Florida ("50 C.F.R. 223.102 - Enumeration of threatened marine and anadromous species," 2014).

Threatened Corals	Currently Known in These U.S. Geographic Areas			
Caribbean Waters	**Florida - Atlantic**	**Puerto Rico**	**U.S. Virgin Islands**	**Gulf of Mexico**
*Acropora cervicornis (Staghorn)**	X	X	X	
*Acropora palmata (Elkhorn)**	X	X	X	X
Mycetophyllia ferox	X	X	X	
Dendrogyra cylindrus	X	X	X	
Orbicella annularis	X	X	X	X
Orbicella faveolata	X	X	X	X
Orbicella franksi	X	X	X	X
Pacific Waters	**Guam**	**Commonwealth of Northern Mariana Islands**	**Pacific Remote Island Areas**	**American Samoa**
Acropora globiceps	X	X	X	X
Acropora jacquelineae				X
Acropora lokani				
Acropora pharaonis				
Acropora retusa	X	X	X	X
Acropora rudis				
Acropora speciosa			X	X
Acropora tenella				
Anacropora spinosa				
Euphyllia paradivisa				X
Isopora crateriformis				X
Montipora australiensis				
Pavona diffluens				
Porites napopora				
Seriatopora aculeata	X	X		

* Listed as threatened in 2006

Table 1: Listing of Threatened Corals and Known Geographic Distributions ("NOAA Lists 20 New Corals as Threatened Under the Endangered Species Act," 2014)

Defining critical habitat for listed species is required by the ESA ("50 C.F.R. 424 - Listing endangered and threatened species and designating critical habitat," 2009). Critical habitat is defined as,

> "(1) the specific areas within the geographical area currently occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (i) essential to the conservation of the species and (ii) that may require special management considerations or protection, and (2) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination by the Secretary that such areas are essential for the

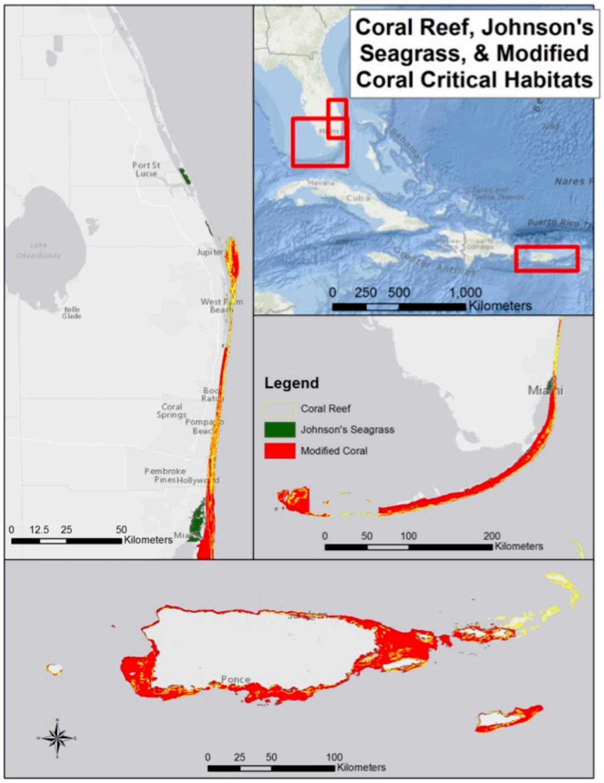

Figure 7: Locations of Critical Johnson's Seagrass and Modified Coral Habitats in the Southeastern U.S. and Caribbean ("Fisheries Data: Critical Habitat," 2014)

conservation of the species.” ("50 C.F.R. 424 - Listing endangered and threatened species and designating critical habitat," 2009, pp. 1054-1055)

Critical habitat has been defined for *Acropora palmata*, *Acropora cervicornis* and *Halophila johnsonii* and can be seen in figure 7 ("50 C.F.R. 424 - Listing endangered and threatened species and designating critical habitat," 2009, pp. 1054-1055). Critical habitat has not yet been defined for the 20 newly listed coral species because their complex biological and physical requirements require further study (*Endangered and Threatened Wildlife and Plants: Final Listing Determinations on Proposal To List 66 Reef-Building Coral Species and To Reclassify Elkhorn and Staghorn Corals*, 2014). Critical habitats for the 20 newly listed coral species are expected to be similar to the critical *Acropora palmata* and *Acropora cervicornis* habitat in that it will likely be comprised of broad areas of water along the coasts of U.S. Caribbean and Indo-Pacific landmasses with general habitat suitable for coral growth.

USCG ATON Impacts to Threatened Coral and Seagrass Species

USCG established and maintains fixed and floating ATON in U.S. waters that are within the critical habitats of *Acropora palmata*, *Acropora cervicornis*, and *Halophila johnsonii* and in areas that will likely be designated as critical habitat for the 20 newly listed coral species ("50

C.F.R. 226 - Designated Critical Habitat," 2010). The following sections will discuss 1) the fixed and floating ATON mechanisms that impact the threatened coral and seagrass species and their benthic environment, 2) the effects of the impacts on those species, 3) a review of the impacts presented in the NMFS Biological Opinion, 4) a worst-case quantification of the area of threatened species' habitat impacted by USCG ATON using geographic information systems (GIS) analysis; and 5) a discussion of habitat impact area differences found between the NMFS Biological Opinion and the GIS analysis.

Fixed ATON Impact Area

As mentioned earlier, fixed ATON are installed by USCG construction tender vessels that stabilize themselves by extending four spuds down to the seafloor while driving the ATON piles (*Aids to Navigation Manual - Structures, COMDTINST M16500.25A*, 2005). The impact areas calculated in the NMFS Biological Opinion assumed a spud bottom surface area of $0.09m^2$ and an ATON pile bottom surface area of $0.16m^2$ ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). These assumed values are also used throughout this paper. Each time a fixed ATON is placed, the area of the seafloor impacted is equal to $4 \times 0.09m^2 = 0.36m^2$ for the spuds and $1 \times 0.16m^2 = 0.16m^2$ for an individual pile, or $0.52m^2$ of total impact. Therefore, during the placement of a single pile fixed ATON, the combined benthic impact area of the spuds ($0.36m^2$) is 2.25 times greater than the impact area of the fixed ATON pile ($0.16m^2$). For multiple pile ATON (ATONs may have from 1 to *n* piles), the pile impact area would be greater by a factor of $0.16m^2$ times *n*, the number of piles. General maintenance of fixed ATON can be completed without the use of vessel spuds; nevertheless, for a worst-case impact assessment, all maintenance activities will be assumed to be completed by spudded-down construction tender vessels. In such a case, each fixed ATON maintenance visit spudding event results in an impact to the seafloor 2.25 times greater than the impact area of a single fixed ATON pile. A fixed ATON is generally visited once every three years for maintenance (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). More frequent visits may be required as physical conditions and wear and tear to ATON equipment and structures dictate (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). Maintenance is typically carried out multiple times over the life of a fixed ATON before its pile system needs to be replaced. Spudding and pile driving operations also temporarily increase suspended sediments in their vicinities ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). The area impacted by the suspended sediments is difficult to quantify and varies based on the unique sediment and physical oceanographic characteristics of each location.

Floating ATON Impact Area

Floating ATON moorings feature a sinker and a section of chain that lay on the seafloor, as shown in figure 6 above (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). Concrete sinkers, the most common type of sinker, vary in bottom area from 0.31m^2 for a 113-227kg sinker to 3.16m^2 for a 6,804-9072kg sinker (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The bottom section of the buoy mooring chain scours the seafloor as the buoy moves within its swing circle on the surface of the water. The chafe section of the chain is the portion of the chain that is constantly in motion and impacts the seafloor as the buoy is acted upon by environmental forcing (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The extent of the benthic habitat that is scoured by the buoy chain varies depending on the scope of chain, tidal range, and environmental forces where the buoy is located. In the GIS analysis section of this paper the worst-case area impacted by each floating USCG ATON within coral habitat was determined using the L-method of buoy excursion calculation that yields the radius of potential chain scouring of the seafloor (*Aids to Navigation Manual - Positioning & Range Surveying, COMDTINST M16500.1D*, 2005). This radius is equal to the length of mooring chain plus the distance from the waterline of the buoy to where the chain connects to the buoy minus the water depth (*Aids to Navigation Manual - Positioning & Range Surveying, COMDTINST M16500.1D*, 2005). See figure 6 above for a depiction of the distance between the buoy waterline and where the chain connects to the buoy below the water.

Sinker area is not factored into the worst-case impact area assessments because the seafloor area impacted by the mooring chain includes and is greater than the area impacted by the sinker. As an example, consider a floating ATON attached to a 9071.8kg sinker with 54.9m of chain. In that case, the benthic area impacted by chain scouring ($4{,}018.7m^2$) includes and is 1,270 times greater than the area impacted by the sinker ($3.16m^2$).

Generally, a floating ATON is visited once every three years for maintenance (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). More frequent visits may be required as physical conditions and wear and tear to ATON equipment and structures dictate (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The laying down and picking up of sinkers and chain associated with floating ATON establishment, disestablishment, and maintenance can temporarily increase turbulence, turbidity, and sedimentation in their vicinities ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Similar to the impacts from fixed ATON spudding and pile driving operations, the area impacted by the suspended sediments is difficult to quantify and varies based on the unique sediment and physical oceanographic characteristics of each location.

Impacts of ATON on Threatened Seagrass and Coral Species

The impact mechanisms of fixed and floating USCG ATON affect the threatened coral and seagrass species through direct contact with the species and their benthic environment and through increased sedimentation ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013).

In the case of Johnson's seagrass, contact with the seagrass and surrounding sediment can damage grass blades and the seagrass' rhizome root system, which can kill the impacted seagrass ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Disturbances of seagrass' belowground biomass hinders organic matter production and nutrient recycling, and destabilizes the sediment substrate which are detrimental to seagrass regrowth (Di Carlo & Kenworthy, 2008). The scouring of a floating ATON mooring chain over the bottom changes the sediment composition by removing smaller sediment particles and exposing larger particles like pebbles, cobbles, and gravel (Herbert, Crowe, Bray, & Sheader, 2009). Organic matter, an important source of nutrients for seagrasses, is removed as well, which hinders seagrass growth (Kenworthy, Fonseca, Whitfield, & Hammerstrom, 2002). Floating ATON mooring chain benthic disturbances also likely negatively impact the abundance and density of macrofaunal invertebrate species that are a critical part of seagrass ecosystems (Herbert et al., 2009).

Recovery of Western Atlantic and Caribbean Ocean seagrasses into damaged habitat areas occurs rather slowly. Small to intermediate sized seagrasses with shallow, small-diameter rhizomes like *Halophila johnsonii*, *Halodule wrightii* (shoalgrass) and *Syringodium filiforme* (manatee grass) can recover their aboveground biomass in around two years (Kenworthy et al., 2002). A large seagrass like *Thalassia testudinum* (turtle grass) that has larger rhizomes and greater belowground biomass can take upwards of 10 years to recover its aboveground biomass (Kenworthy et al., 2002). Seagrass recovery can be deceiving because belowground biomass typically recovers more slowly than aboveground biomass; belowground biomass may take decades to return to its pre-disturbed state (Di Carlo & Kenworthy, 2008).

For the threatened coral species, direct contact with USCG ATON fixed or floating mooring components can cause coral fragmentation, overturning, and abrasion (Dinsdale & Harriott, 2004; "Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Figures 8 and 9 are examples of ATON moorings impacting coral habitats. Coral fragmentation can result in death of the coral fragment or reduced energy devoted to sexual reproduction in favor of injury repair, regrowth, and stabilization ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Coral abrasion causes tissue and skeleton damage that diverts energy away from sexual reproduction and growth toward injury repair and regeneration ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Abraded areas of coral are also more susceptible to disease and to settlement of other organisms like algae, sponges, or other species of coral ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013).

Figure 8: ATON Sinker on Coral (Girton, 2015)

Figure 9: ATON Mooring Chain Scouring Seafloor (Girton, 2015)

The resilience of corals to damage depends largely on their physical morphology (Liddle & Kay, 1987). Encrusting and massive corals are typically more resilient to damage than branching corals because of their low profile and more compact form; and thicker branching corals are typically more resilient than thinner branching corals because of their sturdier skeletal structure (Liddle & Kay, 1987).

Coral reefs will begin to recover after the cause of damage has stopped. An area of damaged reef will recruit algae within a week and barnacles within two weeks (Jaap, 2000). Coralline algae, sponges, octocorals, and stony corals will begin growing within one to two years (Jaap, 2000). It typically takes 8-10 years for the damaged reef to develop high densities of sponges and octocoals and 15-20 years for octocorals to regrow to their pre-damage densities (Jaap, 2000). Because of the slower recruitment and growth rate of stony corals, their full recovery may take several decades to a century (Jaap, 2000).

NMFS Biological Opinion Impact Assessment

The NMFS Biological Opinion of August 5, 2013 was issued before the listing of the 20 new threatened Caribbean and Indo-Pacific coral species in 2014 and only included an analysis of impacts to *Acropora palmata*, *Acropora cervicornis*, and *Halophila johnsonii* ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). USCG ATON impacts to the newly listed coral species should be similarly deleterious and general findings from the Biological Opinion can likely be extended to those species. A thorough characterization of USCG ATON impacts to the newly listed threatened corals would require that the USCG re-consult with NMFS and for NMFS to issue an new Biological Opinion in accordance with section seven of the ESA ("16 U.S.C. 1536 - Interagency cooperation," 2014).

The Biological Opinion affirmed that the USCG's ATON in critical habitats adversely impacts threatened coral and seagrass species ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Despite harming those species, the Biological Opinion found that USCG ATON and associated maintenance activities are not a significant hazard to their habitat or their continued existence ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Specifically, the USCG's continued maintenance of ATON in critical habitats will not "jeopardize [the species'] continued existence" and is not, "likely to destroy or adversely modify [the species'] designated critical habitat" due to the relatively small amount of critical habitat impacted by ATON ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013, pp. 3, 56).

The number of fixed and floating ATON and impacts associated with their installation and maintenance as reported in the NMFS Biological Opinion are presented in table 2 below.

The ATON are broken into two categories, those found within critical *Acropora* and *Halophila johnsonii* habitats and those surveyed and verified to be found in the vicinity of the threatened species.

The Biological Opinion concluded that the impact of fixed ATON on the benthic environment is insignificant because of the relatively small surface area of the pile bottoms ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). The impact of fixed ATON maintenance activities was found to be more significant than pile placement because, as discussed above, the area impacted by a single spudding event is 2.25 times greater than the area impacted by a single pile ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). Despite being more significant, the Biological Opinion concluded that the impact of USCG fixed ATON maintenance activity is discountable and insignificant ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013).

<table>
<tr><td colspan="6">ATON Found Within Critical Habitats</td></tr>
<tr><td colspan="2">ATON Type</td><td colspan="2">Halophila johnsonii Critical Habitat</td><td colspan="2">Acropora palmata & Acropora cervicornis Critical Habitat</td></tr>
<tr><td colspan="2">Fixed</td><td colspan="2">111</td><td colspan="2">252</td></tr>
<tr><td rowspan="4">Impact Assessment</td><td>Action Type</td><td>Maintenance</td><td>Replacement</td><td>Maintenance</td><td>Replacement</td></tr>
<tr><td>Impact Area</td><td>41.25m^2 (note 1)</td><td>18.22m^2 (note 1)</td><td>93.65m^2</td><td>66.70m^2 (note 2)</td></tr>
<tr><td>Total Impact Area</td><td colspan="2">59.47m^2 (note 1)</td><td colspan="2">160.35m^2</td></tr>
<tr><td>% of Critical Habitat</td><td colspan="2">8.16×10^{-5} (note 1)</td><td colspan="2">2.23×10^{-6}</td></tr>
<tr><td colspan="2">Floating</td><td colspan="2">1</td><td colspan="2">186</td></tr>
<tr><td colspan="2">Impact Assessment</td><td colspan="2">N/A</td><td colspan="2">“impacts from sinkers/chains are discountable” (pg. 22)</td></tr>
<tr><td colspan="2">Number of ATON Surveyed for Presence of Threated Species</td><td colspan="2">112 (all)</td><td colspan="2">155 (35%)</td></tr>
<tr><td colspan="6">Note 1: These figures were not calculated in the NMFS Biological Opinion.
Note 2: Figure reported corresponds to an individual pile diameter of 0.58m. A pile diameter of 0.46m was used elsewhere in the Biological Opinion. Recalculating with a pile diameter of 0.46m yields an area of 41.37m^2 and a percent of critical habitat of 5.45×10^{-7}.</td></tr>
</table>

<table>
<tr><td colspan="6">Surveyed ATON Found in the Vicinity of Threatened Species and Calculated Impact Area</td></tr>
<tr><td colspan="2">ATON Type</td><td colspan="2">ATON found within the vicinity of Halophila johnsonii</td><td colspan="2">Aids Found Within 60.96m of a Acropora palmata or Acropora cervicornis colony</td></tr>
<tr><td colspan="2">Fixed</td><td colspan="2">11</td><td colspan="2">14</td></tr>
<tr><td rowspan="3">Impact Assessment</td><td>Action Type</td><td>Maintenance</td><td>Replacement</td><td>Maintenance</td><td>Replacement</td></tr>
<tr><td>Impact Area</td><td>4.09m^2</td><td>1.81m^2</td><td>5.20m^2</td><td>2.28m^2</td></tr>
<tr><td>Total Impact Area</td><td colspan="2">5.10m^2</td><td colspan="2">7.48m^2</td></tr>
<tr><td colspan="2">Floating</td><td colspan="2">0</td><td colspan="2">8</td></tr>
<tr><td colspan="2">Impact Assessment</td><td colspan="2">N/A</td><td colspan="2">“impacts from maintenance of floating ATONs will not adversely affect elkhorn or staghorn coral” (pg. 48)</td></tr>
</table>

Table 2: Summary of NMFS Biological Opinion findings for ATON Found Within Threatened Species’ Critical Habitat and Surveyed ATON Found in the Vicinity of Threatened Species ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013)

Effects of temporary turbulence, turbidity, and sedimentation within the water column were determined to be negligible for both fixed and floating ATON installation and maintenance due to their relatively short duration and limited extent ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013).

The Biological Opinion concluded that the impacts of floating ATON to critical *Acropora palmata*, *Acropora cervicornis*, and *Halophila johnsonii* habitat would be similarly negligible ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013). The Biological Opinion stated, “The descent and ascent of sinkers/chains can be controlled so that they do not impact the bottom with enough force to dislodge any coral skeletons. Thus, we believe that impacts from sinkers/chains are discountable” ("Endangered Species Act - Section 7 Consultation Programmatic Biological Opinion," 2013, p. 22).

Strangely, the Biological Opinion ignored the impact of chain scouring on the seafloor environment. In the subsequent section of this paper, the full range of USCG ATON impacts in critical coral and seagrass habitats, including seafloor chain scouring, will be quantified and interpreted using GIS analysis.

GIS Analysis of USCG ATON Impacts to Threatened Coral and Seagrass Species

Introduction

GIS analysis was used to quantify the number of USCG Federal ATON and their benthic impact areas within the critical habitats of the threatened coral and seagrass species in the U.S. Exclusive Economic Zone (EEZ). The USCG maintains ATON within the waters of the Bahamas and the Marshall Islands (Kwajalein Atoll); however, these aids were not included in this analysis. Fixed, floating, and total ATON benthic impacts were analyzed in three habitat areas: 1) *Halophila johnsonii* critical habitat, 2) modified critical coral habitat, and 3) coral reefs. Figure 10 shows the data sources and derivation of those habitat areas. Critical habitat areas for *Acropora palmata*, *Acropora cervicornis*, and *Halophila johnsonii* are those defined in

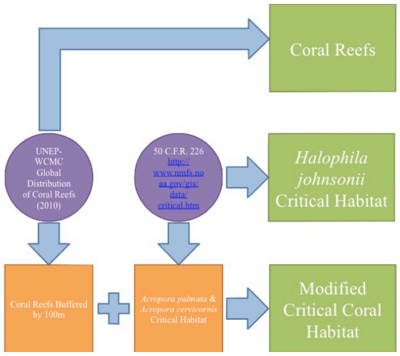

Figure 10: GIS Analysis Habitat Data Sources and Derivation

50 C.F.R. 226. Because critical habitat data for the 20 recently listed ESA threatened coral species has not been defined, critical habitat for those species, for the purposes of this analysis, was defined as existing coral reef areas buffered by 100m. One hundred meter buffered coral reefs were chosen under the reasonable but cautious assumption that areas within 100m of an existing coral reef would meet the definition of critical habitat as discussed in the Overview of Threatened Coral and Seagrass Species section above for the newly listed threatened coral species. The merger of the 100m buffered coral reefs and critical *Acropora* habitat defined modified critical coral habitat for all of the threatened coral species.

Data are presented in the results section for the number and benthic impact area of ATON: 1) located within critical *Halophila johnsonii* habitat, 2) located within modified critical coral habitat, and 3) intersecting an existing coral reef. Benthic impact areas are also calculated for a single visit during a three-year maintenance cycle. A map showing modified critical coral habitat overlaid with critical *Halophila johnsonii* habitat and coral reefs was presented earlier in this paper (figure 7). Additional maps are provided in the results section that provide a visual depiction of ATON benthic impacts to threatened species habitats in Biscayne Bay, FL; Bahia Tallaboa, Puerto Rico; and Apra Harbor, Guam. The Biscayne Bay, FL map is an example of ATON benthic impact areas within critical *Halophila johnsonii* habitat; the Bahia Tallaboa, Puerto Rico map is an example of ATON benthic impact to modified coral reef and coral reef habitats within critical *Acropora* habitat; and the Apra Harbor, Guam map is an example of ATON benthic impact to modified coral reef and coral reef habitats outside of critical *Acropora* habitat.

Data Sources

USCG ATON data was obtained from the USCG's internal Integrated ATON Information System (IATONIS) database. The static USCG ATON data used in this analysis was obtained on March 14, 2015.

Shapefile polygons for the *Acropora* and *Halophila johnsonii* critical habitats were obtained from the NOAA Fisheries GIS Website, http://www.nmfs.noaa.gov/gis/data/critical.htm.

The United Nations Environment Programme (UNEP-WCMC) World Conservation Monitoring Centre's Global Distribution of Coral Reefs (2010) shapefile polygons were used for the coral reef data (UNEP-WCMC, WorldFish Centre, WRI, TNC. 2010).

Landmass polygons were obtained from ArcGIS Online and were titled "World Countries" by user ESRI_dm.

Methods

All GIS analysis was carried out in ESRI's ArcGIS 10.2. The following steps were completed in support of this analysis:

- All data in the data source section were imported into ArcGIS 10.2 and projected into WGS84 World Behrmann, an equal-area cylindrical projection with standard parallels at 30° north and south latitudes.
- USCG federal ATON that intersected critical *Acropora* habitat or were located within 100m of coral reefs and not on land were merged into a single point feature class.
- A point feature class was created of USCG federal ATON that intersected critical *Halophila johnsonii* habitat.

- ATON within the coral and seagrass habitats were reviewed for data quality. ATON apparently entered for training purposes or that had suspect data (i.e. partial/incomplete data entry) were removed. Fixed ATON without the number of piles listed were manually assigned one pile. Some of those ATON may have had more than one pile. Therefore, assigning one pile to those ATON likely underestimated the overall fixed ATON benthic impact area. Floating ATON with no charted water depth listed were manually populated with charted depths obtained from nautical chart images available from NOAA's Online Chart Viewer http://www.nauticalcharts.noaa.gov/mcd/NOAAChartViewer.html.
- Fixed and floating ATON within the modified coral and seagrass critical habitats were separated into distinct feature classes for area impact calculations.
- The radius of circular impact area for each fixed ATON was calculated with the following formula:

  $$Radius\ of\ circular\ impact\ area\ = \sqrt{\frac{Area\ of\ single\ pile\ (\ 0.16m^2) \times Number\ of\ Piles}{\pi}}.$$

  Each ATON pile was assumed to have a diameter of 0.46m and a corresponding area of $0.16m^2$, which conforms to the same assumptions made in the NMFS Biological Opinion.
- The radius of circular impact area for each floating ATON was calculated with the following formula:

  Radius of circular impact area = length of mooring chain + distance from the buoy water line to underwater chain attachment point - charted water depth.

- All technical buoy data was obtained from the Aids to Navigation Manual - Technical, COMDTINST M16500.3A. The length of mooring chain was calculated by adding the chain length segments listed in IATONIS for each aid. The distance from the buoy water line to underwater chain attachment point was calculated in the following manner: 1) for floating ATON with a counterweight and bridle like the one shown in figure 11 – the distance (A) equaled the length of the buoy body (B) minus the minimum allowed buoy freeboard (C) (to approximate the depth of water from the waterline to the bridle attachment point) plus the height of the triangle formed by the bridle's attachment with the mooring chain (D); 2) for floating ATON with mooring chain attached directly to the bottom of the buoy – the distance equaled the buoy draft (the distance the buoy extended below the waterline).

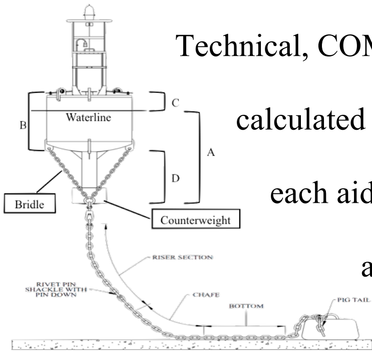

Figure 11: Diagram showing components of the distance from the buoy water line to underwater chain attachment point calculation (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010)

- Each fixed and floating ATON within seagrass and coral habitat was buffered by the radius of circular impact area to calculate benthic impact area.
- Worst-case benthic impact for floating ATON was considered to be the entire circular impact area below each ATON that could be scoured by the mooring chain. In reality, a floating ATON's mooring chain would only likely scour a portion of the impact area as dictated by prevailing environmental conditions and benthic structure.

- Worst-case benthic impact for fixed ATON impacts were considered for the impact area of the existing aid and one visit from a spudded-down construction tender vessel during a three-year maintenance period.
- Individual ATON impact area buffer polygons were dissolved into a single polygon to arrive at a total ATON benthic impact area within each of the habitats.
- A point feature class was created of ATON in modified critical coral habitats that intersected the UNEP-WCMC Global Distribution of Coral Reefs (2010) feature class.
- To determine the area of existing coral reefs potentially impacted by USCG ATON, the ATON coral reef habitat impact area polygons were intersected with the UNEP-WCMC Global Distribution of Coral Reefs (2010). The resulting coral reef polygons were re-intersected with the ATON buffer polygons to determine the coral reef area impact by ATON. Those polygons were dissolved to determine the total coral reef impact area.
- Total areas of critical habitats and coral reefs in the U.S. EEZ were obtained by dissolving the habitat areas into single polygons.

The diagram (appendix A) and python script (appendix b) of the model used in this analysis are included as appendices to this paper.

Results

The major findings from the GIS analysis were that 1) floating ATON have a much greater impact on the critical habitats and coral reefs than fixed ATON (even with fixed maintenance factored in; 2) benthic area impacts from fixed ATON maintenance were greater than the impacts from the fixed ATON piles, and the effect of fixed ATON maintenance was most noteworthy in critical *Halophila johnsonii* habitat; and 3) the percentage of ATON benthic area impacts to the overall habitat areas were very small.

ATON Type	Area		
	Critical *Halophila johnsonii* Habitat	Modified Critical Coral Habitat	Existing Coral Reef Intersecting ATON Benthic Impact Area
Fixed	112	302	70
Floating	1	287	68
Total	113	589	138

Table 3: Number of ATON by Type Found Within Seagrass and Modified Critical Coral Habitat and Intersecting Coral Reefs

Tables of the ATON found in each of the three habitat areas sorted in descending order of impact area are included in appendices C-1 to C-3 of this paper. The maps in figures 12-14 below provide examples of USCG ATON impact areas within *Halophila johnsonii* (figure 12) and modified critical coral habitat (figure 13) and intersecting coral reefs (figure 14).

More fixed than floating ATON were found in each of the habitat areas (table 3). Critical *Halophila johnsonii* habitat had the greatest relative disparity between the number of fixed (112) and floating (1) ATON among the habitat areas (table 3 and figure 15). This was likely the case because fixed ATON best delineated the shallow inshore waterways within the seagrass habitat. See figure 12 for an example of the fixed ATON found within Critical *Halophila johnsonii* habitat in Biscayne Bay, FL. The other two habitat areas were mostly in deeper, offshore areas where floating ATONs were required.

The benthic habitat impact areas associated with floating ATON were much greater than those from fixed ATON. Table 4 presents the results for ATON only impact areas and total habitat percentages and table 5 presents impact areas with the addition of one maintenance visit per fixed ATON. To illustrate the disparity between impact areas caused by fixed versus floating

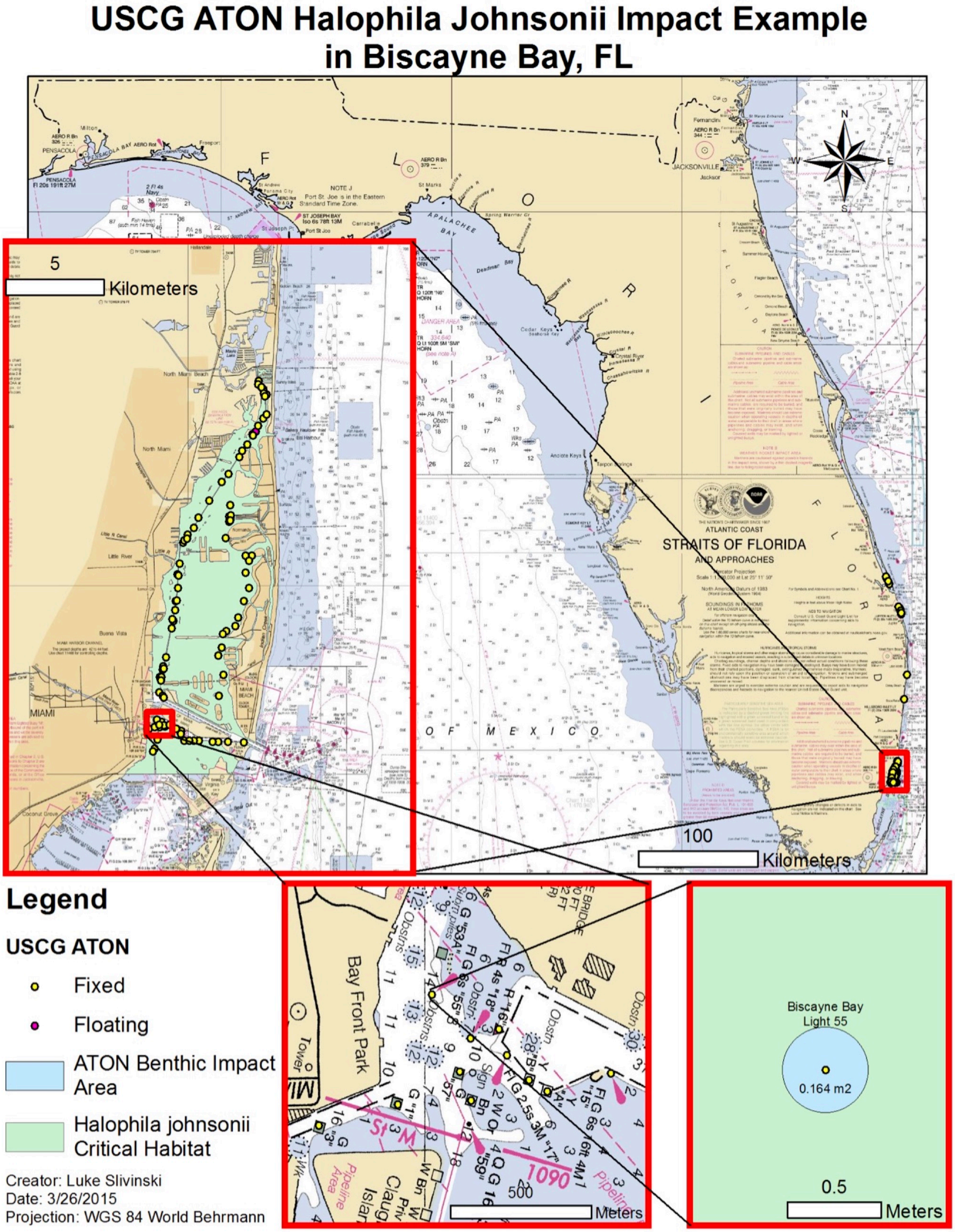

Figure 12: Example of USCG ATON Impact Areas in Critical *Halophila Johnsonii* Habitat

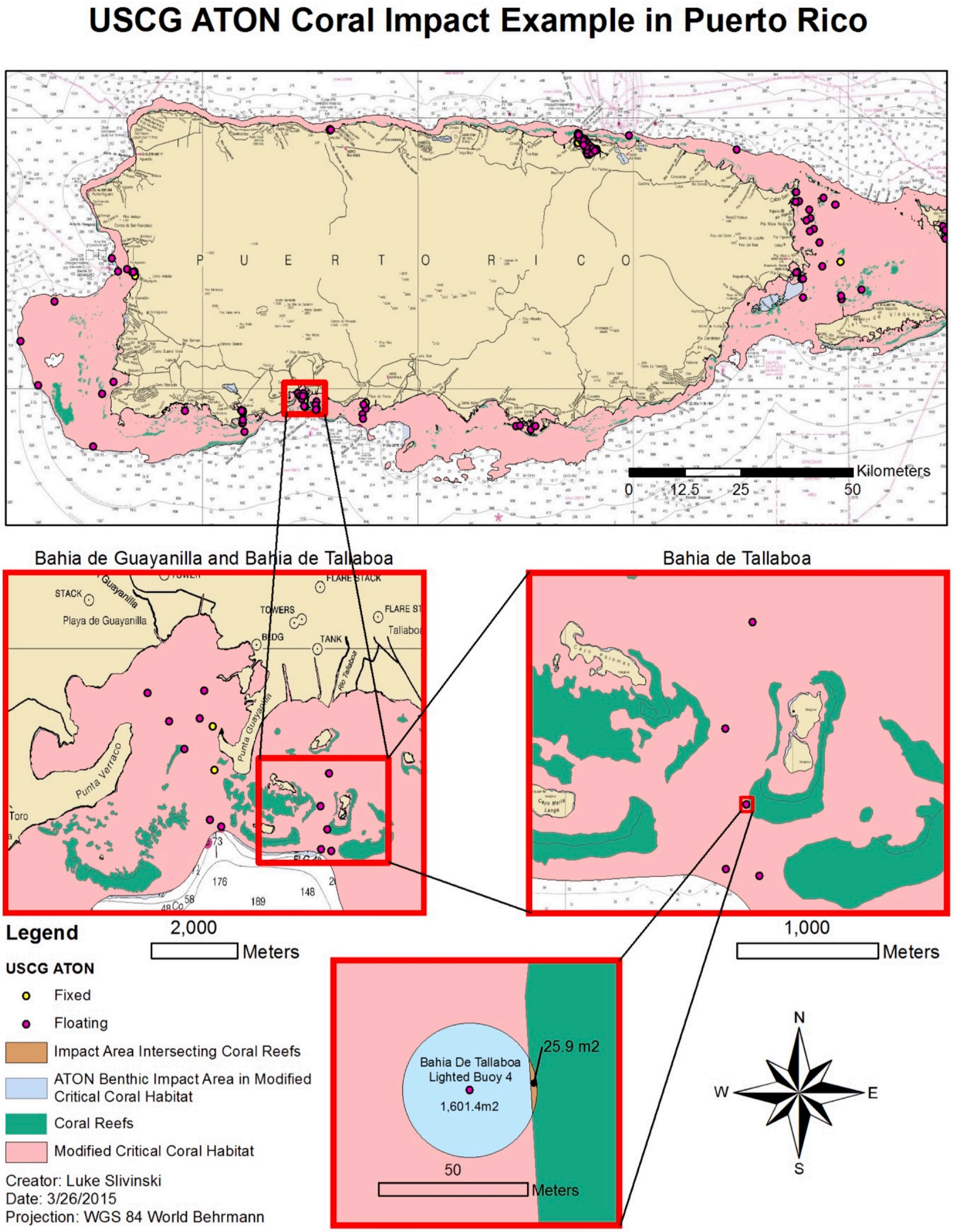

Figure 13: Example of USCG ATON Impact Areas in Modified Critical Coral Habitat

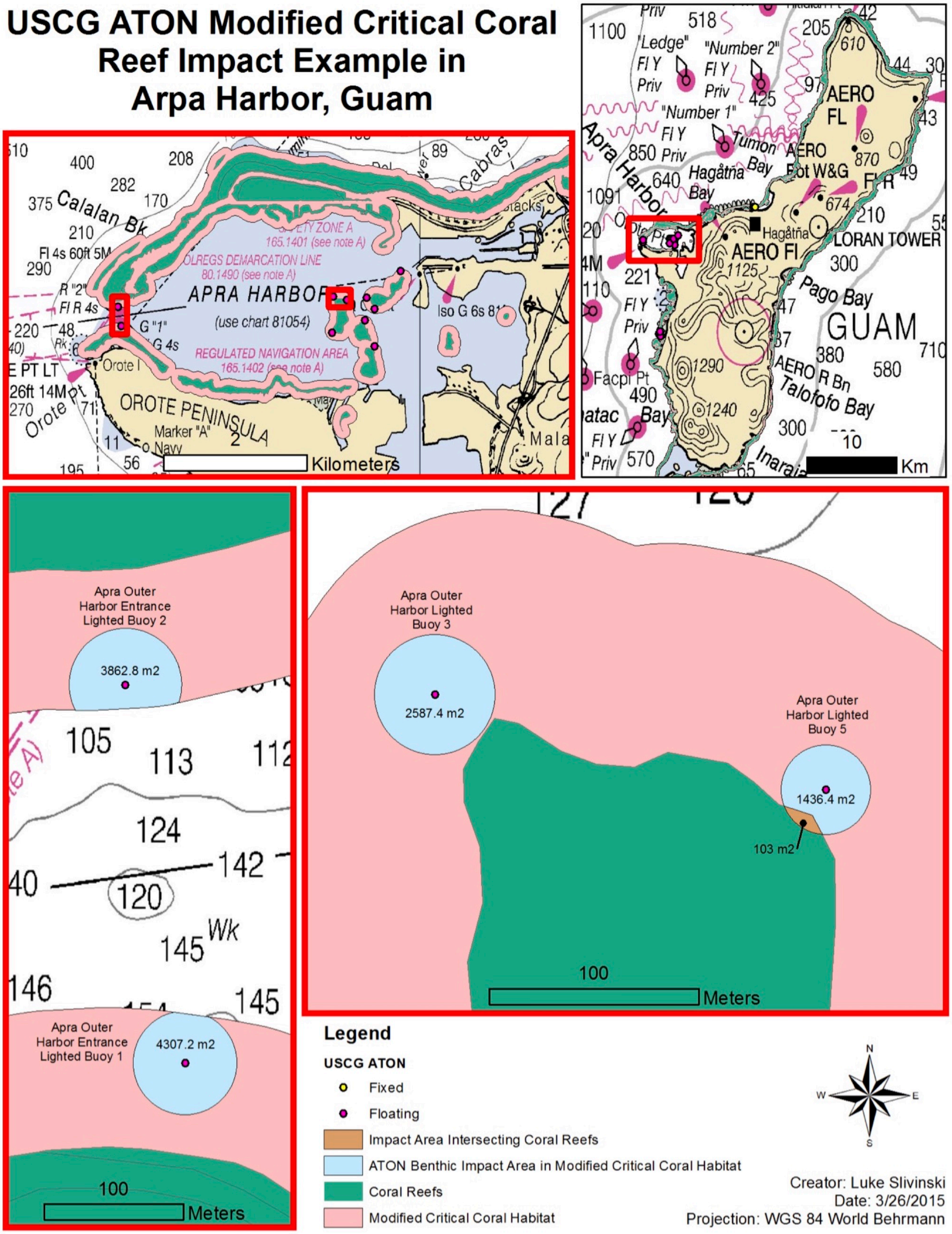

Figure 14: Example of USCG ATON Impact Areas Intersecting Coral Reefs

ATON, the one floating ATON in critical *Halophila johnsonii* habitat represented less than 1% of the ATON found there, but accounted for 62% of the total potential ATON and maintenance benthic impact area.

ATON Only Benthic Impact Area						
	Critical *Halophila johnsonii* Habitat		Modified Critical Coral Habitat		Existing Coral Reef Intersecting ATON Benthic Impact Area	
ATON Type	Area (Ha)	% of Critical Habitat	Area (Ha)	% of Critical Habitat	Area (Ha)	% of Coral Reefs in U.S. EEZ
Fixed	1.87×10^{-3}	2.57×10^{-5}	6.17×10^{-3}	5.03×10^{-7}	1.50×10^{-3}	3.18×10^{-7}
Floating	9.46×10^{-3}	1.30×10^{-4}	55.67	4.53×10^{-3}	8.92	1.89×10^{-3}
Total	1.13×10^{-2}	1.55×10^{-4}	55.68	4.53×10^{-3}	8.92	1.89×10^{-3}

Table 4: ATON Only Benthic Impact Area and Percentages

Worst-Case ATON and Maintenance Benthic Impact Area						
	Critical *Halophila johnsonii* Habitat		Modified Critical Coral Habitat		Existing Coral Reef	
ATON Type	Area (Ha)	% of Critical Habitat	Area (Ha)	% of Critical Habitat	Area (Ha)	% of Coral Reefs in U.S. EEZ
Fixed	5.90×10^{-3}	8.10×10^{-5}	1.70×10^{-2}	1.39×10^{-6}	2.52×10^{-3}	5.34×10^{-7}
Floating	9.46×10^{-3}	1.30×10^{-4}	55.67	4.53×10^{-3}	8.92	1.89×10^{-3}
Total	1.54×10^{-2}	2.11×10^{-4}	55.69	4.54×10^{-3}	8.92	1.89×10^{-3}

Table 5: Worst-case ATON and Maintenance Benthic Impact Area and Percentages

The percentage of benthic impact area from floating ATON versus fixed ATON and maintenance in the modified critical coral habitat (99.96%) and intersecting existing coral reefs (99.97%) was even more significant. Floating ATON benthic impact areas were 1.6 times greater in critical *Halophila johnsonii* habitat, 3,266 times greater in modified critical coral habitat, and 3,538 times greater on coral reefs.

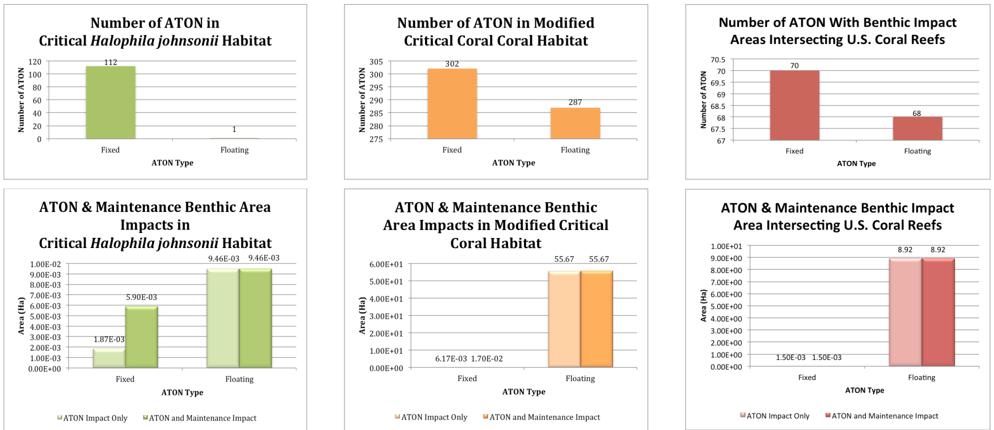

Figure 15: GIS Analysis Charts of the Number of ATON and Benthic Impact Areas Found in Critical *Halophila johnsonii* Habitat, Modified Critical Coral Habitat, and With Impact Areas Intersecting Existing Coral Reefs

The benthic impact area of the one maintenance visit per fixed ATON was greater than the impact of the fixed ATON itself, due to the impact area of the construction tender vessel spuds. Factoring the single maintenance visit into the ATON only impact area calculations (table 4) increased the fixed ATON impact area by the number of ATONs times the surface area of the four construction tender spuds, a total of $0.36m^2$ per fixed ATON. Floating ATON maintenance operations were considered to have no effect on impact area because floating ATON maintenance theoretically does not cause any new damage to the seafloor. The charts in figure 15 show an increase in benthic habitat impact area when fixed ATON maintenance was factored in. In critical *Halophila johnsonii* habitat, fixed ATON maintenance had a noteworthy impact on benthic impact area relative to the impact from the single floating ATON. However, in the other two habitat areas that have more floating ATON, the impact area from fixed ATON and their associated maintenance was so relatively small they are not visible on the charts.

The area percentage of critical habitat and coral reef areas impacted by USCG ATON and maintenance were found to be very small, in all cases less than 0.00454% (table 5). The total habitat areas used to calculate the ATON benthic impact area percentages are listed in table 6.

Habitat	Total Area(Ha)
Halophila johnsonii Critical Habitat	7,289.91
Modified Critical Coral Habitat	1,227,941.61
Coral Reefs in U.S. EEZ	471,673.20

Table 6: Habitat Total Areas

Discussion

The numbers of fixed and floating ATON found within the *Halophila johnsonii* (112 fixed and 1 floating) and *Acropora* (249 fixed and 211 floating) critical habitats were similar to those presented in the NMFS Biological Opinion (*Halophila johnsonii*: 111 fixed and 1 floating and *Acropora* (252 fixed and 186 floating). The slight differences fall within a reasonable range for regular and temporary ATON establishments and disestablishments in the timeframe between the release of the Biological Opinion (2013) and when the data was collected for this analysis.

The fixed ATON impact area percentages in *Halophila johnsonii* (0.0000810%) and *Acropora* (0.000000656%) critical habitats correspond fairly closely with the values presented in the NMFS Biological Opinion (note: the 0.000000656% figure was calculated using the total area of critical *Acropora* habitat (759,494.23Ha), and not modified coral habitat). The differences between fixed ATON impact area percentages found in this analysis and those presented in the Biological Opinion were attributed to differing numbers of fixed ATON and because the Biological Opinion assumed one pile for all fixed ATON, whereas this analysis incorporated multiple-pile fixed ATON data where available. This GIS analysis confirmed the Biological Opinion's finding that while USCG ATON does harm the ESA threatened species, the impacts are relatively insignificant in area and likely do not pose a significant hazard to the threatened species' habitats or their continued existences.

The floating ATON impact area data obtained from this analysis was strikingly different from the negligible impact reported in the NMFS Biological Opinion. This analysis found larger potential benthic impact areas from floating as opposed to fixed ATON in all of the habitats of concern. In the case of modified critical coral habitat and floating ATON impact areas intersecting coral reefs, the impact areas from floating ATON were thousands of times greater than from fixed ATON. The reason why NMFS disregarded the impact of floating ATON mooring chain scouring the seafloor in their impact analysis was not made clear in the Biological Opinion.

The annual ecosystem services value of seagrasses has been calculated at $30,000 per hectare in 2015 U.S. dollars (Costanza et al., 1998; "CPI Inflation Calculator," 2015). Therefore, the 1.54×10^{-2}Ha of critical *Halophila johnsonii* habitat impacted by USCG ATON and maintenance represents a loss of value equal to around $460 per year. The cost to restore FL seagrass habitats has been estimated at $746,000 per hectare in 2015 U.S. dollars, which brings the estimated cost to restore critical *Halophila johnsonii* habitat damaged by USCG ATON and maintenance to $7,300 ("CPI Inflation Calculator," 2015; Fonseca, Kenworthy, & Thayer, 1998). These values only consider USCG ATON and maintenance impact areas in critical *Halophila johnsonii* habitat and do not capture the economic losses associated with USCG ATON and maintenance in all seagrass habitats.

The economic value of U.S. Caribbean coral reefs in terms of fisheries, coastal protection, tourism, and biodiversity has been estimated to be $1.44 billion per year in 2015 U.S. dollars (Cesar, Burke, & Pet-Soede, 2003; "CPI Inflation Calculator," 2015). Factoring in Indo-

Pacific coral reefs in the U.S. EEZ, this value increases to $2.26 billion per year. USCG ATONs negatively impact a worst-case 0.0021 percent of U.S. coral reefs. If those impacts eliminate all economic value of the affected coral reef areas, the total potential economic losses are around $43,000 per year. Costs to restore shallow-water coral reefs like the ones damaged by USCG ATON have averaged around $538,000 per hectare in 2015 U.S. dollars ("CPI Inflation Calculator," 2015; Edwards, Job, & Wells, 2010). Therefore, if coral reef damage from USCG ATON were to cease, the cost to restore the 8.92Ha of potentially damaged coral reefs would equal around $4.8 million.

Recommendations

The USCG should explore options for environmentally friendly ATON mooring alternatives to eliminate or reduce benthic habitat impact areas within critical habitats of the ESA threatened seagrass and coral species. Acknowledgment that USCG ATON benthic impacts within the critical habits are very small in percentage and are unlikely to detrimental to the survival of the threatened species or unduly harm their critical habitats should not be considered justification for inaction. Instead, as responsible stewards of the environment and to demonstrate organizational leadership in environmental management, the USCG should adopt environmentally friendly ATONs where practicable.

Helping to protect or restore areas of coral reefs and seagrass habitats equal to the area impacted by USCG ATON and maintenance would demonstrate responsible environmental stewardship and would help recover some of the lost coral reef and seagrass economic benefits and ecosystem services. Given the potential damage to coral reefs caused by USCG ATON that cost an estimated $43,000 per year in lost economic benefits and would cost about $4.8 million to restore to an undamaged state, the USCG should consider becoming impact neutral by supporting coral reef conservation or restoration projects. The USCG should also consider calculating ATON and maintenance impact areas in all seagrass habitats and support restoration or recovery efforts for that area of seagrass habitat.

Floating ATON benthic habitat impact areas in the habitats of concern are much greater than impacts from fixed ATON. The USCG should consider replacing the one floating ATON found in critical *Halophila johnsonii* habitat (Biscayne Bay Buoy 7B) with a fixed ATON or an environmentally friendly buoy mooing. The removal of that buoy and replacement with a single-pile ATON would reduce the overall USCG ATON impact (including one maintenance visit per fixed ATON) within critical *Halophila johnsonii* habitat by 9.37×10^{-3}Ha (39%), for a total of 5.99×10^{-3}Ha, which would reduce the impacted critical habitat percentage to 0.0000822%.

Marginal reductions to fixed ATON impact areas may be possible by reducing the number of fixed ATON, using smaller diameter piles where possible, reengineering construction vessel spudding equipment or adopting other ship stabilizing technology, or reducing the frequency of fixed ATON and maintenance requiring spudding. Reducing the frequency of spudding events would be especially beneficial in critical *Halophila johnsonii* habitat because the cumulative impacts from spudding are the greatest source of benthic impact area in that habitat over time.

Far greater reductions to benthic habitat impact areas are possible with floating ATON mooring designs that eliminate or reduce the area of the mooring anchor and the amount of mooring rode in contact with the seafloor. The USCG should consider replacing traditional floating ATON moorings in the critical habitats with environmentally friendly moorings. Priority for replacement should be given to floating ATON with potential benthic impact areas that intersect coral reefs. The list of USCG floating ATON with benthic impact areas that intersect coral reefs sorted in descending order of coral reef impact area is included in appendix C-3 of this report. The remainder of this paper will review existing environmentally friendly buoy mooring technologies and their suitability for use with USCG floating ATON. Viable technologies will be described in terms of specifications, installation and maintenance procedures, and costs.

The USCG Research and Development Center recently started a project (November 10, 2014) to consider the adoption of environmentally friendly ATON titled "Develop an Environmentally Friendly Buoy Mooring System" (project number 2702) (Girton, 2015, p. 40). The project is in its early phases and is progressing along an established timeline that includes deadlines for conducting market research (September 2015), issuing requests for proposals (October 2015), drafting a prototype design report (March 2017), prototype testing (March 2019), and delivering the final prototype testing report (May 2019). The most recent project action was the USCG Research and Development Center's submission of a request for information on www.FedBizOpps.gov on February 25, 2015 to solicit information from vendors regarding floating ATON mooring technologies and systems that reduce benthic habitat impact areas (Carnes, 2015). The request for information defined the operating conditions (table 7) expected of viable environmentally friendly floating ATON systems and sought information regarding specifications, environmental impact, acquisition cost, deployment and retrieval procedures, expected service life and maintenance cycle, and life cycle costs (Carnes, 2015). This project is encouraging and demonstrates the USCG's commitment to addressing floating ATON

Operating Condition	Parameter
Buoy Hull Type	6X16LFR or 8X22LFR (foam buoys)
Water Depth	9.1-15.2m
Bottom Type	Sand or Mud
Current	2-4 knots
Wind	0-70 knots
Seas	0-4.3m

Table 7: USCG Expected Operational Capabilities of an Environmentally Friendly Floating ATON System (Carnes, 2015).

mooring benthic impacts in critical habitats. It also puts environmentally friendly floating ATON on an established path toward acceptance and operational use.

Environmentally Friendly ATON Moorings

Introduction

Environmentally friendly buoy moorings reduce benthic habitat impacts (Demers et al., 2013). They are fairly common and are widely used for boat moorings and marker buoys in seagrass and coral habitats across the globe (Halas, 1997). These mooring buoy programs started after the recognition that the seafloor scouring associated with swing-type chain catenary boat moorings and boat anchoring was having negative impacts in sensitive coral and seagrass habitats. Figure 16 shows damage done to a seagrass habitat by swing-type chain catenary boat moorings in Lake Macquarie, New South Wales, Australia. Examples of areas where environmentally friendly buoys have widespread usage are the Florida Keys National Marine Sanctuary (876 mooring/marker buoys) (Becker, 2015); the Virgin Islands National Park in St. John, USVI (200+ mooring buoys) ("Virgin Islands Mariner's Resource Protection Guide," 2010); and Moreton Bay, Queensland, Australia (15+ mooring buoys) ("Environmentally Friendly Moorings," 2015). The Florida Keys National Marine Sanctuary has one of the largest and longest-standing environmentally friendly mooring buoy inventories in the world; and have set

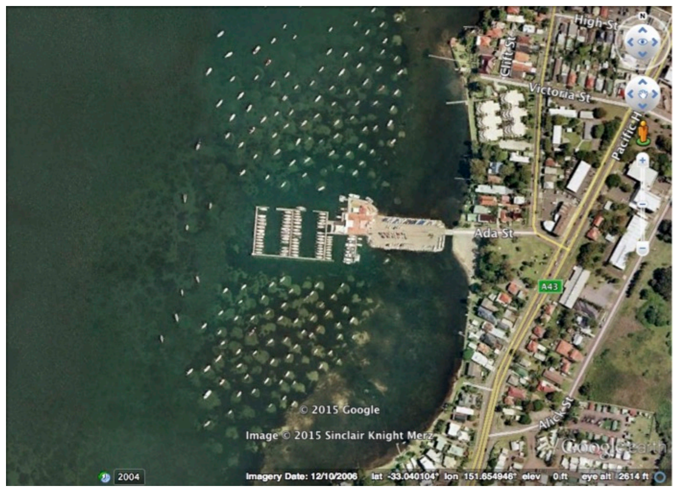

Figure 16: Google Maps Image of Boat Mooring Field in Lake Macquarie, New South Wales, Australia ("Lake Macquarie, New South Wales, Australia," 2015)

the standard for mooring configurations, materials used, and installation and maintenance procedures (Becker, 2015).

Environmentally friendly buoy moorings feature some form of anchoring system and have a method of keeping the mooring line between the anchor and the buoy off the seafloor. Environmentally friendly buoy moorings in more exposed locations also typically feature some method of dampening shock loads from dynamic tensions resulting from currents, wind, and seas ("Mooring Buoy Planning Guide," 2005; Paul et al., 1999).

The commercially available environmentally friendly buoy mooring technologies described below demonstrate the feasibility of reducing benthic impacts from floating USCG ATON through the use of those technologies. These technologies are not a one-size-fits-all solution. Each traditional USCG floating ATON mooring replaced with an environmentally friendly one will have to have to be analyzed on a case-by-case basis to ensure the new mooring is adequate for the ATON’s unique situation (buoy size, water depth, currents, seas, storm events, etc.). The USCG should consider conducing an engineering analysis of environmentally friendly ATON mooring configurations to verify the manufacturers’ claims and confirm the suitability for use with USCG floating ATON. The Woods Hole Oceanographic Institute’s Cable software (available from Dr. Jason Gobat of the University of Washington’s Applied Physics Laboratory, jgobat@uw.edu) is capable of accurately modeling dynamic forces on buoy moorings and could be used the find the optimal environmentally friendly mooring configuration for each floating ATON (J. I. Gobat & Grosenbaugh, 1999; Jason I. Gobat & Grosenbaugh, 2001a, 2001b; Paul et al., 1999).

Anchoring Technology

Popular anchoring methods include concrete blocks, helix anchors, manta ray anchors, and pins cemented or epoxied into hardbottom (figure 17) (Halas, 1997; "Mooring Buoy Planning Guide," 2005). Concrete blocks rely on their weight to anchor a buoy whereas the other three rely on their embedment into the seafloor for their holding force (Halas, 1997; "Mooring Buoy Planning Guide," 2005). Concrete blocks simply sit on the seafloor and can be used on any bottom substrate; helix and manta ray anchors are best suited for soft sediment, mud, sand, and loose rubble; and pins are effective in hard substrates (Halas, 1997; "Mooring Buoy Planning Guide," 2005).

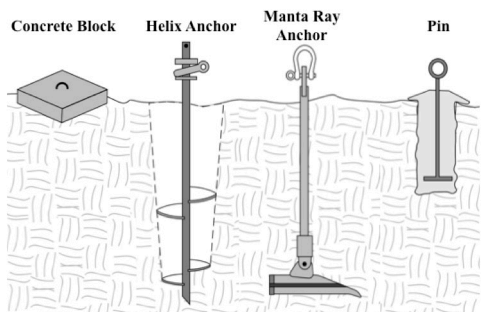

Figure 17: Environmentally Friendly Buoy Mooring Anchor Types (not to scale) ("Mooring Buoy Planning Guide," 2005)

Helix anchors are screwed into the seafloor and can feature multiple helices of differing diameters for additional holding power ("Mooring Buoy Planning Guide," 2005). Helix anchors are most effectively installed with a hydraulic torque motor with a capacity of at least 4,745Nm ("Mooring Buoy Planning Guide," 2005). They can be installed by divers or by spudded-down vessels in shallow water ("Mooring Buoy Planning Guide," 2005).

Manta ray anchors are installed using an underwater jackhammer (hydraulic 40.8kg class jackhammer recommended to minimize turbidity versus a pneumatic version) that drives a steel rod placed into the foot of the vertically oriented anchor (figure 18) ("Marine Anchors Equipment List and Installation Procedures," 2014). When the desired depth is reached, the drive steel is removed and the anchor assembly is pulled upward, which turns the foot 90° and sets the anchor ("Marine Anchors Equipment List and Installation Procedures," 2014). Foresight Products, the manufacturer of the manta ray anchor, sells a device called an Anchor

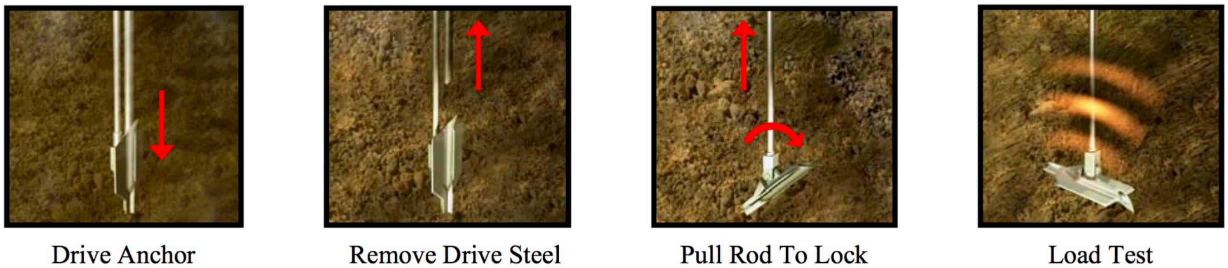

Figure18: Manta Ray Anchor Installation ("Marine Anchors Equipment List and Installation Procedures," 2014)

Locker that proof loads the anchor while setting it, which verifies the anchor's holding capacity ("Marine Anchors Equipment List and Installation Procedures," 2014).

A typical eye pin used in hardbottom installations is made of 316 stainless steel, is 45.72cm long, has a 1.59cm diameter, and has a 4.76cm cross piece welded to the bottom (Halas, 1997). Eye pins are installed into hardbottom by drilling a 5.08cm hole to an appropriate depth and cementing the pin in with Portland Type II cement (Halas, 1997). A knurled or threaded eye pin can also be installed with two-part underwater adhesive epoxy by drilling the hole only 0.36cm wider than the diameter of the pin (Halas, 1997). The smaller diameter pin hole is quicker to drill and the setting strength of the epoxy on the knurled or threaded pin eliminates the need for welding the "T" piece at the end of the pin (Halas, 1997). The epoxy can be mixed and applied simultaneously while underwater, which prevents cement from having to be mixed on the boat and sent down to the hole (Halas, 1997). Using epoxy saves time because divers do not have to retrieve the cement from the surface and eliminates turbidity in the water associated with transporting and applying the cement underwater (Halas, 1997). A final advantage of epoxy over cement is epoxy cures and a load can be applied in 24 hours whereas cement takes several days to cure (Halas, 1997).

One advantage of the helix, manta, and pin anchors over concrete blocks are that they impact a smaller area of the seafloor. The largest (~9,000kg) concrete block used in USCG

ATON moorings has a benthic impact area of 3.16m^2 (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). A large helix anchor (0.356m diameter blade) impacts 0.10m^2 during installation and 0.0011m^2 over a long term from the diameter of the shaft (3.8cm) ("Mooring Buoy Planning Guide," 2005). The largest manta ray anchor (model MR-SR) impacts 0.036m^2 surface area during installation and 0.0005m^2 over a long term from the diameter of the shaft (2.5cm) ("Models," 2014). A 1.91cm diameter bore hole drilled for an eye pin installed with epoxy impacts 0.00028m^2 of the seafloor (Halas, 1997). While an environmentally friendly anchor impacts a smaller area of the seafloor than a concrete block, continuing to use concrete block anchors with an environmentally friendly rode (one that keeps the mooring off the seafloor) would still result in a significant reduction to benthic impact areas.

A second advantage of the helix, manta, and pin anchors over concrete blocks are their superior potential holding power (table8) (Halas, 1997; "Mooring Buoy Planning Guide," 2005). Caution must be used when comparing holding power between anchor designs because the

Anchor Type	Maximum Holding Force	Notes
9,000kg Concrete Block	4,487kg	Calculation for largest USCG concrete block based on testing that has shown that concrete blocks lose about half their holding power when submerged in water.
Manta Ray Anchor	18,151kg	Manufacturers published maximum holding force for all marine manta anchor models.
Helix Anchor	9,483+kg	Pull test conducted with a tugboat. The testing rig's hawser failed at 9,483kg.
Pin	9,177kg (concrete) 11,931kg (epoxy)	Both tests performed with 1.59cm 316 stainless steel pins in limestone substrate. Both pins' metal failed at those force levels, but did not pull out of the substrate.

Table 8: Maximum tested/published holding forces for environmentally friendly anchor types (Halas, 1997; "Marine Anchors Equipment List and Installation Procedures," 2014; "Mooring Buoy Planning Guide," 2005).

holding power of any embedment anchor is highly dependent on the composition of the substrate (Halas, 1997; "Marine Anchors Equipment List and Installation Procedures," 2014; "Mooring Buoy Planning Guide," 2005). For instance, the largest manta ray anchor has a maximum holding force of 18,144kg in dense clay, sand, or gravel and 1,814-5,443kg in peat or organic silts ("Marine Anchors Equipment List and Installation Procedures," 2014). Concrete blocks typically lose about half their weight in breakout force when submerged in water (i.e. a 9,000kg concrete block's holding strength in water is around 4,500kg) (Leonard, 2014; "Mooring Buoy Planning Guide," 2005). Additional holding power for all of the anchor types can be achieved by using multiple anchors for a single mooring, which may be prudent in exposed locations and in areas prone to severe weather conditions (Halas, 1997; "Mooring Buoy Planning Guide," 2005). Assuming suitable seafloor substrate, the superior holding strength of the environmentally friendly anchors should be capable of holding the current chain catenary type floating ATONs currently in use by the USCG. Furthermore, buoy moorings with elastic components in the rode (discussed below) have been shown to experience about 1/3 of the load range and peak tension associated with chain catenary moorings, which provides further evidence that environmentally friendly anchor options are suitable for mooring USCG ATON (Paul et al., 1999).

Rode Technology

Environmentally friendly ATON moorings keep the mooring off the seafloor. In existing environmentally friendly ATON mooring technologies this is accomplished through the floatation provided by the surface buoy or the incorporation of a subsurface buoy and/or an elastomeric component into the mooring rode. Any, all, or a combination of these technologies can be applied USCG ATON in critical habitats. Each floating USCG ATON would have to have a mooring designed to meet the unique requirements of individual buoys.

A mooring system that relies solely on the flotation of the surface buoy to keep the mooring off the seafloor (figure 19) may be fine for ATON moorings in protected harbors with no threat of severe weather, but is likely not a viable option for ATON moorings in more exposed locations because the mooring would come under extreme tension and shock loading during storm events.

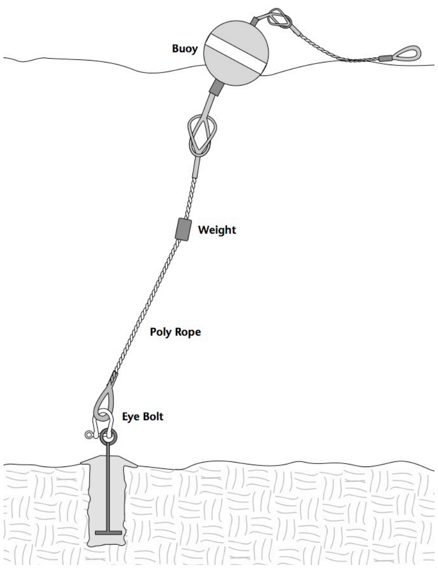

Figure 19: Environmentally Friendly Buoy Mooring that Relies on the Flotation of the Surface Buoy to Keep the Mooring Off the Seafloor (Halas, 1997)

This basic mooring can be made more applicable for USCG floating ATON by adding a subsurface buoy and incorporating an S-tether into the mooring (figure 20) (Han & Grosenbaugh, 2006). The S-shaped inverse catenary introduced into the mooring allows for an increased length of mooring rode, which helps absorb dynamic forces and makes the mooring more resilient to storm surges and extreme weather events (Han & Grosenbaugh, 2006). S-tether moorings are still susceptible to being stretched taut by environmental forcing (wind, current, waves, storm surge), which puts them at risk of parting from shock loading and extreme dynamic forces.

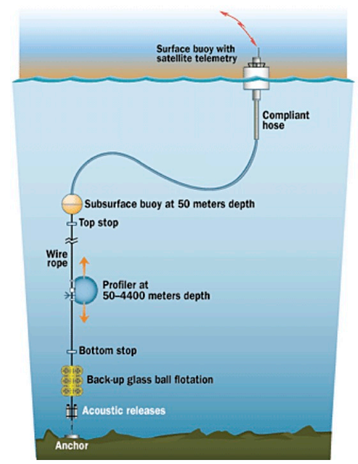

Figure 20: Example of an S-Tether Mooring with a Subsurface Float ("Platforms," 2015)

Incorporating an elastic component into an ATON mooring can help dampen dynamic forces and improve the mooring's resiliency to storm surges and extreme weather events. As mentioned earlier, a buoy mooring with an elastic component may experience three times less peak tension than a traditional chain catenary mooring (Paul et al., 1999).

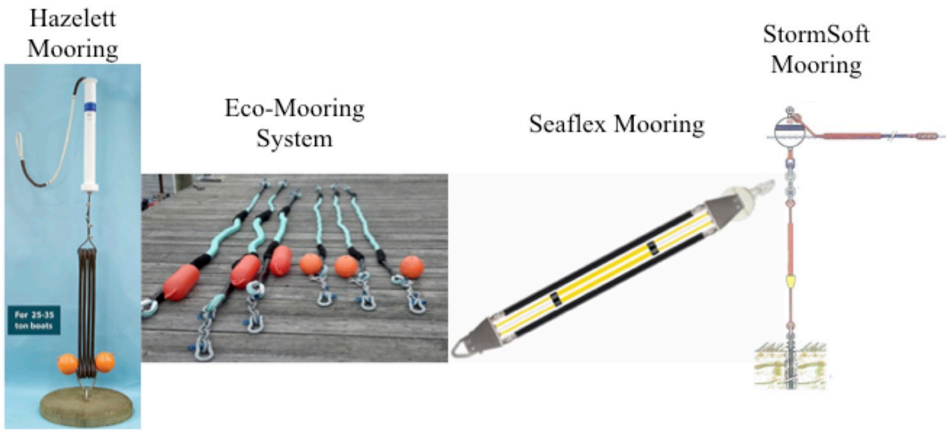

Figure 21: Commercially Available Environmentally Friendly Buoy Mooring Systems ("Eco-Mooring Rodes," 2014; "Seaflex Mooring System," 2012; "Single Point Mooring Systems," 2015; "StormSoft Boat Moorings," 2015)

Customizable elastic mooring components and complete buoy mooring systems are available from several commercial vendors (figure 21). Hazelett moorings feature one or more elastic polyurethane bands ("Single Point Mooring Systems," 2015). The Eco-Mooring System features elastic cords surrounded by 12-strand polyfiber rope for added energy absorption and strength ("Eco-Mooring System," 2014). The Seaflex mooring features from 1 to 10 rubber hawsers secured at either end by integrated shackles ("Seaflex Mooring System," 2012). The StormSoft Mooing features multi-strand rubber cords wrapped in a braided polyester rope ("Conservation Mooring Study," 2013).

Commercially Available Environmentally Friendly Buoy Mooring System	Description	Maximum Holding Capacity
Hazelett Mooring	2.4m x 4.4cm elastic member	31,700kg boat weight
Eco-Mooring System	3.7m x 5.1cm elastic member	31,298kg breaking strength
Seaflex Mooring	10-rod system (.6m to 22.9m long)	13,608kg breaking strength Suitable for boats weighing up to 181,437kg
StormSoft Elastic Boat Mooring	3m elastic member	8,164kg to 10,886kg tensile strength

Table 9: Maximum Reported Holding Capacities of Commercially Available Environmentally Friendly Buoy Mooring Systems ("Conservation Mooring Study," 2013).

The maximum advertised holding capacities of the commercially available environmentally friendly mooring systems are presented in table 9. The holding capacity measures vary by manufacturer, which makes direct comparisons between them challenging. The heaviest floating ATON found in the critical habitats was an 8X21LR buoy, which weighs approximately 6,300kg (*Aids to Navigation Manual - Technical, COMDTINST M16500.3A*, 2010). The heaviest foam buoy (8X22LFR) identified in the USCG Research and Development Center's Request for Information weighs 3,175kg ("8X22LFR Data Sheet," 2015). Assuming those ATON behave the same in the water as boats of similar weight, all of the commercially available environmentally friendly ATON moorings have configuration options apparently suitable for mooring both buoys. Therefore, to minimize costs when transitioning to environmentally friendly floating ATON moorings, the USCG may be able to continue using existing steel buoys until the end of their service life and not have to replace them with lighter foam buoys. Reusing existing steel buoys instead of replacing them with the foam models referenced in the Coast Guard Research and Development Center's request for information could save between $23,000 (for a 6X16LFR foam buoy) and $35,000 (for a 8X22LFR foam buoy) per mooring ("Foam Buoy Option Year 4 Price List," 2014).

The performance and reliability of commercially available environmentally friendly moorings in unprotected, open-ocean conditions where some USCG ATON are moored is uncertain. For instance, anecdotal reporting from a competing manufacturer indicated the designs of the Seaflex and Hazelett mooring systems induce vibration into the moorings when exposed to water currents, which can lead to their premature failure (Lefebvre, 2015). Elastic mooring components are also somewhat fragile and are susceptible to damage and failure from contact and entanglement with fishing gear (Paul et al., 1999). Additionally, synthetic mooring lines used in many environmentally friendly mooring systems are susceptible to damage from fish and shark bites, which weaken the strength of the line and could contribute to the line parting under strain and the failure of the mooring (Berteaux, Prindle, & May, 1987; Lefebvre, 2015). The commercially available environmentally friendly mooring options discussed in this paper were designed primarily for mooring boats in protected waters. Moorings for USCG ATON must be capable of withstanding constant exposure to open-ocean seas and currents and occasional storm-force conditions. The expected environmental conditions a USCG ATON must be capable of enduring (table 7) are 2-4 knots of current, 0-70 knots of wind, and 0-4.3m seas (Carnes, 2015).

Another major challenge when evaluating the existing environmentally friendly mooring anchors and rode systems is the lack of an independent and objective scientific study that compares the moorings' ecological efficacy, holding strength, durability, resilience to storm events, service life, maintenance requirements, and costs ("Conservation Mooring Study," 2013). Prototype testing should be conducted to understand and overcome these challenges and to determine the suitability of environmentally friendly moorings for USCG ATON anchored in a range of environmental conditions. The USCG Research and Development Center's project includes this critical prototype testing. Operational prototype testing is planned for four locations in Florida (figure 22) (Huff, 2015). These appropriately-selected locations will test the moorings' capabilities and durability in exposed, semi-exposed, and protected locations (Huff, 2015). In the event of a prototype mooring failure, the four locations are outside of critical *Halophila johnsonii* and coral habitats which should prevent damage to those particularly sensitive habitats (Huff, 2015). The prototype testing locations are also nearby ATON servicing

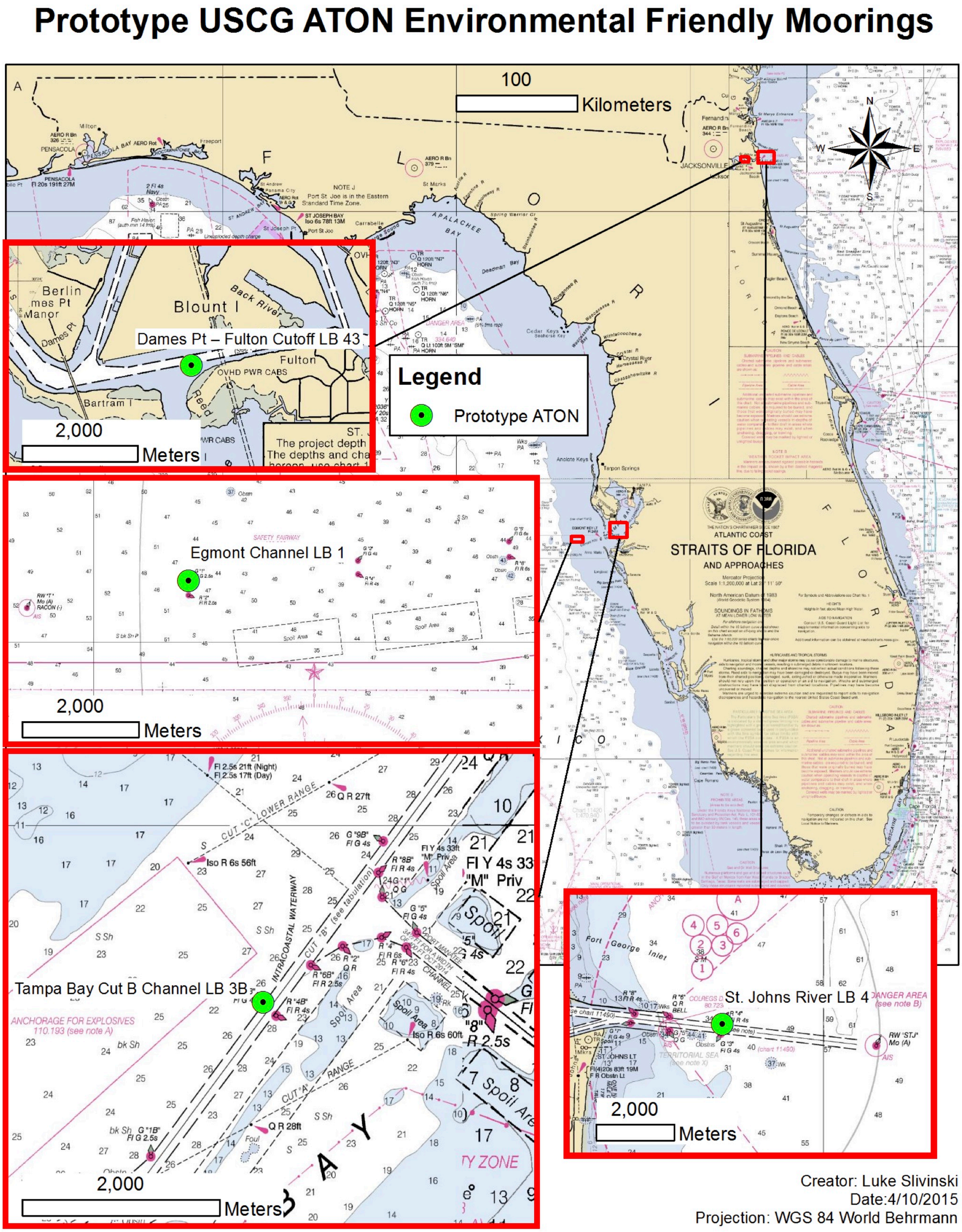

Figure 22: Prototype Environmentally Friendly Testing Locations (Huff, 2015)

units, which will minimize the response time for retrieving adrift buoys and facilitates the timely replacement of failed moorings (Huff, 2015).

Installation Procedures

In most cases, environmentally friendly ATON moorings will require divers for installation. Helix and manta ray anchors can be installed from a vessel but require the installing vessel to be spudded down for stability. This is not ideal because spudding causes damage to the seafloor. Even if a ship installed an anchor, divers would still be required to attach the mooring rode to the anchor.

If concrete blocks are used to anchor the moorings, they could potentially be installed and retrieved by USCG buoy tender vessels without the use of divers, but the process would be complicated by the stretchy and somewhat fragile nature of elastic mooring components. Seaflex moorings can include a bypass line that engages and takes the strain before the elastic component is stretched to its breaking point ("Seaflex Brochure," 2012). A similar bypass line may be able to be incorporated across the elastic portion of other environmentally friendly mooring systems. A bypass system could potentially enable a buoy tender vessel to lift and lower an environmentally friendly mooring without parting or damaging the elastic component. However, testing of bypass systems and the development of standard operating procedures for shipboard mooring installation and retrieval would be required. A bypass line, regardless if used for mooring installation and recovery, could also be beneficial because it may prevent the loss of a buoy and subsequent damage to the surrounding environment if the fragile elastic portion of the rode were to part.

Environmentally friendly anchors can typically be installed by divers in under an hour ("Mooring Buoy Planning Guide," 2005). Concrete block, helix, and manta ray anchors can be immediately attached to a buoy mooring, which streamlines the installation process. For a pin or pins installed into hardbottom, cure time (24 hours for epoxy and several days for cement) delays mooring attachment ("Mooring Buoy Planning Guide," 2005). Attaching an environmentally friendly mooring to an anchor by divers and ATON deployment should also take less than an hour. Altogether, accounting for delays associated with transitioning between installation phases, an environmentally friendly anchor and ATON mooring installation by divers should be completed in less than three hours ("Mooring Buoy Planning Guide," 2005).

Maintenance Procedures

Environmentally friendly mooring inspections and maintenance are best carried out by divers (Becker, 2015; "Mooring Buoy Planning Guide," 2005). An annual inspection and maintenance cycle is recommended (Becker, 2015; "Conservation Mooring Study," 2013; "Mooring Buoy Planning Guide," 2005). During the annual visit, the mooring should be inspected with particular attention given to shackles and attachment points; worn components should be replaced and the buoy and mooring should be scraped clean of marine growth (Becker, 2015; "Mooring Buoy Planning Guide," 2005). Scraping marine growth off of the buoy and mooring is critical for preventing damage to the mooring line and elastic mooring components from sharp or abrasive marine organisms (Becker, 2015). The Florida Keys National Marine Sanctuary mooring buoy maintenance program has developed a hinged tool that can be closed around a synthetic mooring line to scrape the line around its circumference (Becker, 2015). They have also developed a pressure washer adapter to remove marine growth that closes around a mooring line and sprays the line from all directions around its circumference (Becker, 2015). Synthetic mooring line should be replaced every three to five years and as required between scheduled replacements (Becker, 2015; "Conservation Mooring Study," 2013). The elastic portion of the mooring can be expected to last between 7-10 years and should be replaced as needed ("Conservation Mooring Study," 2013). To conduct more effective maintenance and save time on the water, especially for maintenance requiring the replacement of mooring components, the entire mooring can be swapped with a new or recently refurbished mooring ("Mooring Buoy Planning Guide," 2005). The old mooring can then be thoroughly inspected, cleaned, and repaired back on land.

The Florida Keys National Marine Sanctuary has had an effective environmentally friendly mooring buoy program in place for over 30 years, making them one of the foremost authorities on mooring maintenance (Becker, 2015). David "Hank" Becker is a supervisor on the Sanctuary's mooring buoy maintenance staff and is an indispensable source of environmentally friendly mooring maintenance knowledge. Hank Becker can be contacted at david.becker@noaa.gov or (305) 852-7717 ext. 38.

Costs

Costs are discussed below for environmentally friendly anchor and mooring system equipment and for installation of a single mooring (anchor and rode) by commercial and USCG divers. The equipment costs presented for the environmentally friendly anchors (table 10) are for the largest available helix and manta ray anchor models and for a single 1.59cm diameter stainless steel pin.

Anchor Type	Approximate Cost
9,000kg Concrete Block	$600
Manta Ray Anchor	$150
Helix Anchor	$700
Pin	$100

Table 10: Approximate Costs of Environmentally Friendly Anchors ("Concrete Price Considerations – Cost of Concrete," 2015; "Manta Ray Anchors," 2015; "Mooring Buoy Planning Guide," 2005)

Pricing information was solicited from the four environmentally friendly mooring manufacturers to moor the USCG's 8X21LR, 6X16LFR, and 8X22LFR buoys in 13.3m of water (the average charted water depth for floating ATON in modified critical coral habitat) with the current, wind, and sea conditions as listed in the USCG Research and Development Center's request for information (table 7). The 8X21LR buoy was the heaviest (6,300kg) USCG floating ATON found in modified critical coral habitat. The 6X16LFR and 8X22LFR buoys were the two foam buoys referenced in the USCG Research and Development Center's request for information. No pricing information was received from the manufacturers for a variety of reasons. No response was received for the Eco-Mooring System. Seaflex Inc. forwarded the request to the engineering firm NavigationsTeknik AB that designs their buoy mooring systems; no response was received from NavigationsTeknik AB as of the writing of this paper (Hylland, 2015). Hazelett Marine LLC responded saying they have worked unsuccessfully with the USCG in the past to design and test navigational aids moored with their system; and that their, "environmentally friendly system is a feasible replacement for bottom scouring chain systems, but our best efforts with research, time, and money spent, to convince the Coast Guard, have failed" (Hill, 2015). Hazelett Marine LLC's willingness to deal further with the USCG is questionable. New England Marine LLC said their StormSoft Mooring would not be appropriate for mooring those types of USCG ATON in open-ocean-like conditions outlined in the request for information (Lefebvre, 2015). However, New England Marine LLC estimated that their StormSoft mooring would be suitable for use with about half of existing USCG ATON in more protected locations (Lefebvre, 2015).

Considering no pricing information was received from the manufacturers, pricing information is presented for the four environmentally friendly moorings from a 2013 "Conservation Mooring Study" prepared by the Urban Harbors Institute, University of Massachusetts Boston. The pricing information was based on the following environmental conditions: 6.1m of water with a 1.2m tidal range and a maximum of 43kts of wind and 1kt of

Mooring System	Approximate Cost
Chain (18.3m long, 3.8cm diameter links)	$1,282
Hazelett Mooring	$2,571
Eco-Mooring System	$1,864
Seaflex Mooring	$1,742
StormSoft Elastic Boat Mooring	$2,267

Table 11: Approximate Costs of Mooring System Equipment for an 8X21LR buoy in 6.1m of water ("Conservation Mooring Study," 2013; "Large Chain Prices 2015," 2015)

current ("Conservation Mooring Study," 2013). The mooring systems listed in table 11 are capable of holding a 17m non-commercial power boat or, in the case of the Hazelett Mooring system, a boat weighing 14,515kg, which is sufficient to moor the heaviest (8X21LR) USCG buoy in the given environmental conditions ("Conservation Mooring Study," 2013).

From an equipment cost standpoint, the cost of an environmentally friendly anchor is similar in cost to a traditional concrete block anchor; however, the cost of an environmentally friendly mooring rode is greater than the cost of a traditional chain catenary rode. The cost to construct a traditional 9,000kg concrete block anchor is around $600, which is within the range of the costs of environmentally friendly mooring anchors ("Concrete Price Considerations – Cost of Concrete," 2015). The cost to moor an 8X21LR buoy in 6.1m of water with 18.3m (three times the depth of water) of 3.8cm diameter chain in a traditional chain catenary mooring (not including the cost of the anchor) would be $1,282 ("Large Chain Prices 2015," 2015). The cost to moor that ATON with an environmentally friendly rode (average cost of ($2,111) would be 64% greater than the cost of a traditional chain catenary rode.

Costs to install environmentally friendly ATON moorings would vary depending on location, anchor installation method, proximity to other ATON being replaced, etc. Estimated costs are presented below for replacing a single floating ATON in the vicinity of Key West, Florida by both commercial and USCG divers. Commercial divers should be readily available in Florida, Puerto Rico, the U.S. Virgin Islands, and Hawaii; however, their services may not be practical or feasible in some locations like remote Indo-Pacific islands. The cost calculations were based on the following conditions:

- The employment of four divers.
- An hourly wage of $23.36/hour for commercial divers ("Occupational Employment and Wages, May 2014, 49-9092 Commercial Divers," 2015).
- Local USCG divers with no labor, travel, or per diem costs.
- The use of a USCG 55-foot Aids to Navigation Boat as a dive and mooring installation platform.
- A one hour transit time to and from the buoy.
- The installation of a manta ray anchor and the USCG's prior purchase of required manta ray anchor installation equipment (load locker - $1,749, drive steels - $900, jackhammer - $2,250, and portable hydraulic power unit - $4,300) ("Manta Ray Anchors," 2015).
- A total installation time of three hours.

The total man-hours associated with installing the mooring would be 20 hours (4 divers times 2 hours of transit and 3 hours of installation) at a cost of about $470. The total estimated equipment and commercial diver installation costs for each of the four environmentally friendly mooing options using a manta ray anchor is summarized in table 12. Total costs for moorings using other anchor types can be calculated by substituting in the costs of the alternate anchors (table 10).

Utilizing the USCG divers and the 55-foot Aids to Navigation Boat would not come at an additional cost to the USCG, but the value associated with their use is significant. The inside government reimbursable standard rate for the 55-foot Aids to Navigation Boat and crew would

Mooring System	Rode Cost	Manta Ray Anchor Cost	Commercial Diver Labor	Total Cost
Hazelett Mooring	$2,571	$150	$470	$3,191
Eco-Mooring System	$1,864	$150	$470	$2,484
Seaflex Mooring	$1,742	$150	$470	$2,362
StormSoft Elastic Boat Mooring	$2,267	$150	$470	$2,887

Table 12: Total Approximate Cost of Commercial Diver Installation of Environmentally Friendly ATON Moorings with Manta Anchors ("Conservation Mooring Study," 2013)

total $25,600 (5 hours at an hourly rate of $5,120/hour) (*Coast Guard Reimbursable Standard Rates, COMDTINST 7310.1P*, 2015). Assuming a USCG dive team composition of 1 Lieutenant ($78/hour), 2 First Class Petty Officers ($56/hour each), and 1 Second Class Petty Officer ($49/hour) the inside government reimbursable standard rate for their 5 hours of employment would total $1,195 (*Coast Guard Reimbursable Standard Rates, COMDTINST 7310.1P*, 2015).

Maintenance costs for environmentally friendly ATON are difficult to forecast because they would vary by mooring system, mooring component deterioration rate, ATON location, rate of marine growth buildup, and severity of dynamic environmental forces. Annual diver maintenance of environmentally friendly ATON moorings would likely be more costly than the triennial maintenance of traditional ATON moorings. However, annual maintenance visits from local divers deployed from small boats could possibly be cheaper than triennial maintenance visits from much larger and more costly to operate USCG buoy tenders that must transit greater distances from more distant homeports. Environmentally friendly ATON mooring components could possibly be replaced less frequently and at a lower cost than components of traditional chain catenary moorings. Long-term testing of environmentally friendly moorings would be required to make an accurate maintenance cost comparison with traditional floating ATON moorings.

Conclusion

USCG fixed and floating ATON negatively impact the critical habitats of ESA listed threatened *Halophila johnsonii* and coral habitats. Far more benthic area is potentially damaged by floating ATON mooring chain scouring the seafloor than by fixed ATON piles and their associated maintenance. In the case of coral reefs and coral habitat the potential impact areas from floating ATON are thousands of times greater than the impacts from fixed ATON and their associated maintenance.

The annual losses in ecosystems services value from USCG fixed and floating ATON impact areas total an estimated $460 in critical *Halophila johnsonii* habitat and $43,000 in coral habitats (Cesar et al., 2003; Costanza et al., 1998). The estimated costs to restore the impacted areas are $7,300 in critical *Halophila johnsonii* habitat and $4.8 million in coral habitats (Edwards et al., 2010; Fonseca et al., 1998).

The impact area percentages of USCG fixed and floating ATON within threatened species' habitats calculated in this study were very small, in all cases less than 0.00454%. This confirms the finding of the 2013 NMFS biological opinion that while USCG ATONs negatively impact threatened seagrass and coral species, they are not detrimental to the survival of those species.

The USCG should demonstrate their commitment to environmental stewardship by reducing benthic impact areas associated with fixed and floating ATON and by becoming impact neutral by supporting seagrass and coral reef conservation or recovery projects equal in area to the areas impacted by USCG ATON.

ATON impact areas in critical *Halophila johnsonii* habitat could be reduced by replacing the one floating ATON found there with a fixed ATON or an environmentally friendly buoy mooring; and by minimizing the number of USCG construction tender vessel spudding events. The greatest reduction to benthic impact areas could be realized through the replacement of floating ATON moorings in critical seagrass and coral habitats with environmentally friendly buoy moorings. These types of moorings are engineered to keep the mooring off of the seafloor and have widespread and long-term (greater than 30 years) usage across the globe for boat moorings in sensitive habitats. Several commercially available environmentally friendly mooring anchors and rode systems are capable of holding the largest USCG floating ATON found in the critical habitats. The environmentally friendly mooring options should perform well in protected areas with fairly calm sea conditions; however, their effectiveness is questionable in exposed, open-ocean sea conditions where some USCG ATON are moored.

The cost of an environmentally friendly mooring anchor is similar to the cost of a traditional concrete block anchor; but environmentally friendly mooring rodes are more costly (around 60% greater in one particular application) than the costs of traditional chain catenary moorings. Installation and maintenance costs may be greater for environmentally friendly moorings because their installation and maintenance are best performed by divers, which represent an additional cost over typical shipboard ATON operations. The recommended annual maintenance interval for environmentally friendly moorings will also likely result in higher costs over traditional ATONs' triennial maintenance schedule.

The USCG should conduct an engineering analysis of commercially available environmentally friendly mooring systems to determine their suitability for mooring USCG ATON across their range of exposure to environmental forces. Environmentally friendly ATON moorings would also have to be engineered specifically for each ATON's unique buoy type, bottom type, tidal range, and environmental conditions.

The USCG recently (November 2014) started a Research and Development Center project on environmentally friendly floating ATON moorings. The project demonstrates the USCG's commitment to environmental conservation through the elimination or reduction of negative environmental impacts. The project's established timelines, planned prototype testing, and required reports are firm and promising steps toward the operational deployment of these systems by the year 2019.

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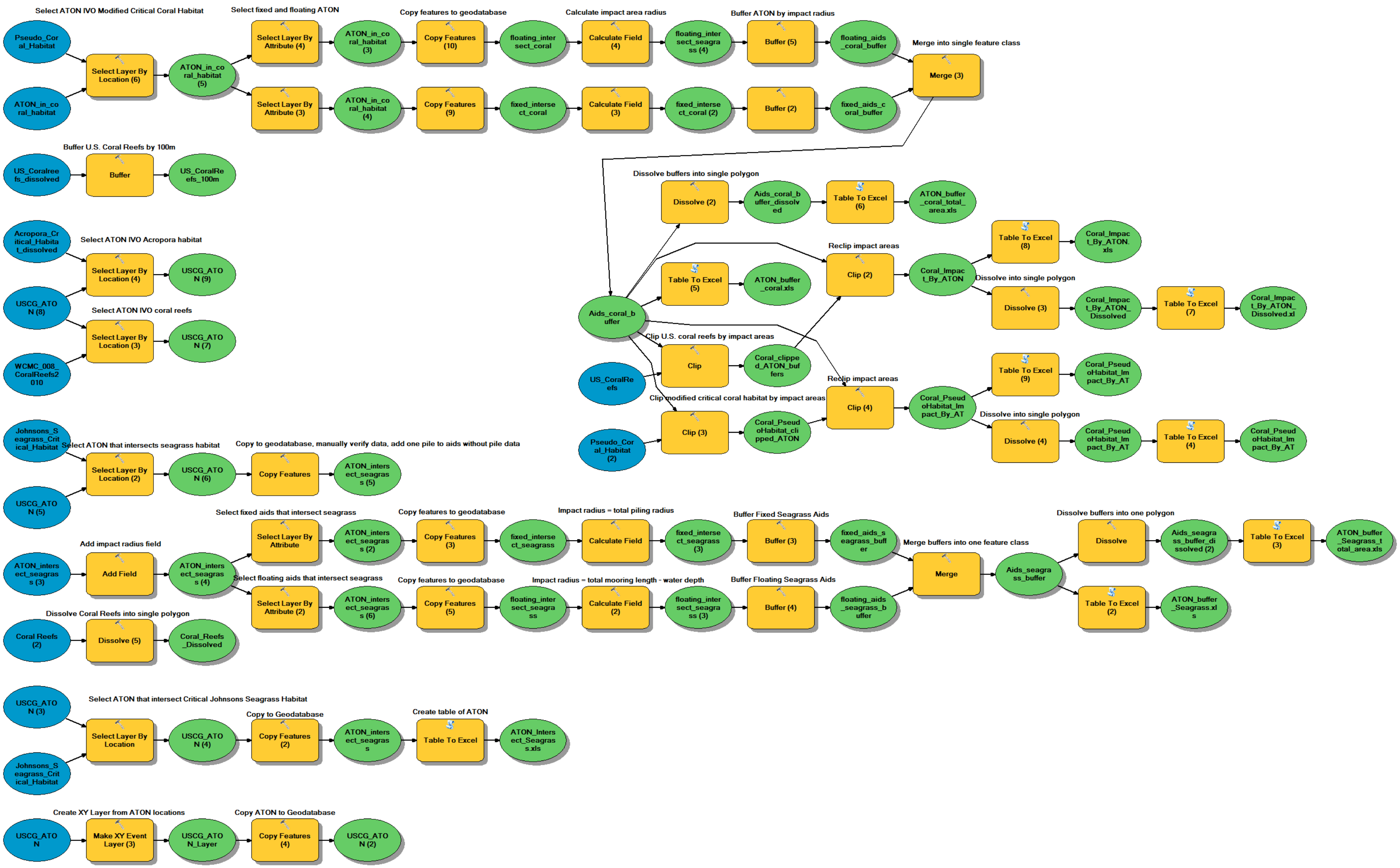
Appendix A

GIS Analysis Model Graphic



Appendix B

GIS Model Python Script

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# ATON Model Script.py
# Created on: 2015-03-23 22:15:02.00000
#   (generated by ArcGIS/ModelBuilder)
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

# Set Geoprocessing environments
arcpy.env.scratchWorkspace = "Z:\\MP\\GIS\\Scratch"
arcpy.env.outputCoordinateSystem =
"PROJCS['World_Behrmann',GEOGCS['GCS_WGS_1984',DATUM['D_WGS_1984',SPHEROID['WGS_1984',63
78137.0,298.257223563]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Behr
mann'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0.0],PARAMETER['Central_Meridian',
0.0],UNIT['Meter',1.0]]"
arcpy.env.geographicTransformations = ""
arcpy.env.workspace = "Z:\\MP\\GIS\\Data\\CoralAids.gdb"


# Local variables:
USCG_ATON = "Z:\\MP\\GIS\\Data\\USCG_ATON.mdb\\USCG_ATON"
Johnsons_Seagrass_Critical_Habitat = "Johnsons_Seagrass_Critical_Habitat"
USCG_ATON__3_ = "USCG_ATON"
ATON_intersect_seagrass__3_ = "ATON_intersect_seagrass"
Coral_Reefs__2_ = "Coral Reefs"
USCG_ATON__5_ = "USCG_ATON"
Johnsons_Seagrass_Critical_Habitat__2_ =
"Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Johnsons_Seagrass_Critical_Habitat"
USCG_ATON__8_ = "USCG_ATON"
WCMC_008_CoralReefs2010 = "WCMC_008_CoralReefs2010"
Acropora_Critical_Habitat_dissolved = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Acropora_Critical_Habitat_dissolved"
World_Countries = "World_Countries"
US_Coralreefs_dissolved = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\US_Coralreefs_dissolved"
ATON_in_coral_habitat = "ATON_in_coral_habitat"
WCMC_008_CoralReefs2010__2_ = "WCMC_008_CoralReefs2010"
Pseudo_Coral_Habitat = "Pseudo_Coral_Habitat"
Pseudo_Coral_Habitat__2_ = "Pseudo_Coral_Habitat"
ATON_in_Critical_Coral_Habitat__2_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\ATON_in_Critical_Coral_Habitat"
USCG_ATON_Layer = "USCG_ATON_Layer"
USCG_ATON__2_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\USCG_ATON"
USCG_ATON__4_ = "USCG_ATON"
ATON_intersect_seagrass = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\ATON_intersect_seagrass"
ATON_Intersect_Seagrass_xls = "Z:\\MP\\GIS\\Data\\ATON_Intersect_Seagrass.xls"
fixed_intersect_seagrass__3_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_intersect_seagrass"
fixed_aids_seagrass_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer"
ATON_intersect_seagrass__4_ = "ATON_intersect_seagrass"
ATON_intersect_seagrass__2_ = "ATON_intersect_seagrass"
fixed_intersect_seagrass = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_intersect_seagrass"
ATON_intersect_seagrass__6_ = "ATON_intersect_seagrass"
```

Appendix B

```
floating_intersect_seagrass = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_intersect_seagrass"
floating_intersect_seagrass__3_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_intersect_seagrass"
floating_aids_seagrass_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer"
Aids_seagrass_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Aids_seagrass_buffer"
Aids_seagrass_buffer_dissolved__2_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Aids_seagrass_buffer_dissolved"
ATON_buffer_Seagrass_xls = "Z:\\MP\\GIS\\Data\\ATON_buffer_Seagrass.xls"
ATON_buffer_Seagrass_total_area_xls = "Z:\\MP\\GIS\\Data\\ATON_buffer_Seagrass_total_area.xls"
Coral_Reefs_Dissolved = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_Reefs_Dissolved"
USCG_ATON__6_ = "USCG_ATON"
ATON_intersect_seagrass__5_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\ATON_intersect_seagrass"
USCG_ATON__9_ = "USCG_ATON"
US_CoralReefs_100m = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\US_CoralReefs_100m"
fixed_intersect_coral__2_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_intersect_coral"
fixed_aids_coral_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer"
ATON_in_coral_habitat__5_ = "ATON_in_coral_habitat"
ATON_in_coral_habitat__4_ = "ATON_in_coral_habitat"
fixed_intersect_coral = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_intersect_coral"
ATON_in_coral_habitat__3_ = "ATON_in_coral_habitat"
floating_intersect_coral = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_intersect_coral"
floating_intersect_seagrass__4_ = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_intersect_coral"
floating_aids_coral_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer"
Aids_coral_buffer = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Aids_coral_buffer"
Aids_coral_buffer_dissolved = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Aids_coral_buffer_dissolved"
ATON_buffer_coral_xls = "Z:\\MP\\GIS\\Data\\ATON_buffer_coral.xls"
ATON_buffer_coral_total_area_xls = "Z:\\MP\\GIS\\Data\\ATON_buffer_coral_total_area.xls"
Coral_clipped_ATON_buffers = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_clipped_ATON_buffers"
Coral_Impact_By_ATON = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_Impact_By_ATON"
Coral_Impact_By_ATON_Dissolved = "Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_Impact_By_ATON_Dissolved"
Coral_Impact_By_ATON_Dissolved_xls = "Z:\\MP\\GIS\\Data\\Coral_Impact_By_ATON_Dissolved.xls"
Coral_Impact_By_ATON_xls = "Z:\\MP\\GIS\\Data\\Coral_Impact_By_ATON.xls"
Coral_PseudoHabitat_clipped_ATON_buffers =
"Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_PseudoHabitat_clipped_ATON_buffers"
Coral_PseudoHabitat_Impact_By_ATON =
"Z:\\MP\\GIS\\Data\\CoralAids.gdb\\Coral_PseudoHabitat_Impact_By_ATON"
Coral_PseudoHabitat_Impact_By_ATON_Dissolved =
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Coral_PseudoHabitat_Impact_By_ATON_Dissolved_xls =
"Z:\\MP\\GIS\\Data\\Coral_PseudoHabitat_Impact_By_ATON_Dissolved.xls"
Coral_PseudoHabitat_Impact_By_ATON_xls = "Z:\\MP\\GIS\\Data\\Coral_PseudoHabitat_Impact_By_ATON.xls"

# Process: Make XY Event Layer (3)
arcpy.MakeXYEventLayer_management(USCG_ATON, "LONGITUDE", "latitude", USCG_ATON_Layer,
"GEOGCS['GCS_WGS_1984',DATUM['D_WGS_1984',SPHEROID['WGS_1984',6378137.0,298.257223563]],PR
IMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]];-400 -400 1000000000;-100000 10000;-100000
10000;8.98315284119522E-09;0.001;0.001;IsHighPrecision", "")

# Process: Copy Features (4)
arcpy.CopyFeatures_management(USCG_ATON_Layer, USCG_ATON__2_, "", "0", "0", "0")

# Process: Select Layer By Location
arcpy.SelectLayerByLocation_management(USCG_ATON__3_, "INTERSECT",
Johnsons_Seagrass_Critical_Habitat, "", "NEW_SELECTION")

# Process: Copy Features (2)
arcpy.CopyFeatures_management(USCG_ATON__4_, ATON_intersect_seagrass, "", "0", "0", "0")
```

Appendix B

```
# Process: Table To Excel
arcpy.TableToExcel_conversion(ATON_intersect_seagrass, ATON_Intersect_Seagrass_xls, "NAME", "CODE")

# Process: Add Field
arcpy.AddField_management(ATON_intersect_seagrass__3_, "ImpactRadius", "DOUBLE", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Select Layer By Attribute
arcpy.SelectLayerByAttribute_management(ATON_intersect_seagrass__4_, "NEW_SELECTION", "AID_SUBTYPE = 'Fixed'")

# Process: Copy Features (3)
arcpy.CopyFeatures_management(ATON_intersect_seagrass__2_, fixed_intersect_seagrass, "", "0", "0", "0")

# Process: Calculate Field
arcpy.CalculateField_management(fixed_intersect_seagrass, "ImpactRadius", "Sqr ( (0.16417322* [PILING_COUNT])/3.14159265359)", "VB", "")

# Process: Buffer (3)
arcpy.Buffer_analysis(fixed_intersect_seagrass__3_, fixed_aids_seagrass_buffer, "ImpactRadius", "FULL", "ROUND", "NONE", "")

# Process: Select Layer By Attribute (2)
arcpy.SelectLayerByAttribute_management(ATON_intersect_seagrass__4_, "NEW_SELECTION", "AID_SUBTYPE = 'Floating'")

# Process: Copy Features (5)
arcpy.CopyFeatures_management(ATON_intersect_seagrass__6_, floating_intersect_seagrass, "", "0", "0", "0")

# Process: Calculate Field (2)
arcpy.CalculateField_management(floating_intersect_seagrass, "ImpactRadius", "(!FINAL_MOORING_LENGTH_ft_! - float(!CHARTED_WTR_DEPTH!))*.3048", "PYTHON_9.3", "")

# Process: Buffer (4)
arcpy.Buffer_analysis(floating_intersect_seagrass__3_, floating_aids_seagrass_buffer, "ImpactRadius", "FULL", "ROUND", "NONE", "")

# Process: Merge
arcpy.Merge_management("Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer;Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer", Aids_seagrass_buffer, "AID_UID \"AID_UID\" true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_UID,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_UID,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_UID,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_UID,-1,-1;NAME \"NAME\" true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,NAME,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,NAME,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,NAME,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,NAME,-1,-1;Latitude \"Latitude\" true true false 8 Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Latitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,Latitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,Latitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Latitude,-1,-1;Longitude \"Longitude\" true true false 8 Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Longitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,Longitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,Longitude,-1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Longitude,-1,-1;AID_TYPE \"AID_TYPE\" true
```

Appendix B

true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_TYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_TYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_TYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_TYPE,-1,-1;AID_SUBTYPE
\"AID_SUBTYPE\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_SUBTYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_SUBTYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,AID_SUBTYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,AID_SUBTYPE,-1,-1;DISTRICT \"DISTRICT\"
true true false 4 Long 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,DISTRICT,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,DISTRICT,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,DISTRICT,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,DISTRICT,-1,-1;DESCRIPTION_TYPE
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,DESCRIPTION_TYPE,-1,-
1;GROUP_JURISDICTION \"GROUP_JURISDICTION\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,GROUP_JURISDICTION,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,GROUP_JURISDICTION,-1,-1;STATE
\"STATE\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,STATE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,STATE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,STATE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,STATE,-1,-1;CHARTED_WTR_DEPTH
\"CHARTED_WTR_DEPTH\" true true false 255 Text 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,CHARTED_WTR_DEPTH_UNIT,-1,-
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1;INSPECTION_NEXT_DATE \"INSPECTION_NEXT_DATE\" true true false 8 Date 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,INSPECTION_NEXT_DATE,-1,-
1;HULL_ONSCENE \"HULL_ONSCENE\" true true false 255 Text 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,HULL_ONSCENE,-1,-

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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,HULL_ONSCENE,-1,-
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\"RELIEF_INTERVAL\" true true false 2 Short 0 0
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1;RELIEF_NEXT_DATE \"RELIEF_NEXT_DATE\" true true false 8 Date 0 0
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\"Num_of_Sinkers\" true true false 2 Short 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Num_of_Sinkers,-1,-1;SINKER1 \"SINKER1\"
true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,SINKER1,-1,-
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\"SINKER1_UNIT\" true true false 255 Text 0 0
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true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,SINKER2,-1,-
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true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,SINKER3,-1,-
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\"SINKER3_UNIT\" true true false 255 Text 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,SINKER3_UNIT,-1,-1;SINKER4 \"SINKER4\"
true true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,SINKER4,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,SINKER4,-1,-

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\"UNIT_NAME\" true true false 255 Text 0 0
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\"UNIT_ROLE\" true true false 255 Text 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,UNIT_ROLE,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,UNIT_ROLE,-1,-1;MOORING_LENGTH
\"MOORING_LENGTH\" true true false 8 Double 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,MOORING_LENGTH,-1,-
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1;MOORING_LENGTH_UNIT \"MOORING_LENGTH_UNIT\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,MOORING_LENGTH_UNIT,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,MOORING_LENGTH_UNIT,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,MOORING_LENGTH_UNIT,-1,-
1;FINAL_MOORING_LENGTH_ft_ \"FINAL_MOORING_LENGTH_ft_\" true true false 8 Double 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,FINAL_MOORING_LENGTH_ft_,-1,-
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1;FOUNDATION_TYPE \"FOUNDATION_TYPE\" true true false 255 Text 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,FOUNDATION_TYPE,-1,-1;PILING_COUNT
\"PILING_COUNT\" true true false 2 Short 0 0
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,PILING_COUNT,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,PILING_COUNT,-1,-1;TOT_PILE_RADIUS
\"TOT_PILE_RADIUS\" true true false 8 Double 0 0
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\"PILING_AREA_ft2_\" true true false 8 Double 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,PILING_AREA_ft2_,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,PILING_AREA_ft2_,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,PILING_AREA_ft2_,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,PILING_AREA_ft2_,-1,-1;ImpactRadius
\"ImpactRadius\" true true false 0 Double 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,ImpactRadius,-1,-
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true true false 0 Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,BUFF_DIST,-
1,-1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,BUFF_DIST,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,BUFF_DIST,-1,-1;ORIG_FID \"ORIG_FID\" true
true false 0 Long 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,ORIG_FID,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_seagrass_buffer,ORIG_FID,-1,-
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1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,ORIG_FID,-1,-1;Shape_Length \"Shape_Length\"
false true true 8 Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Shape_Length,-
1,-1;Shape_Area \"Shape_Area\" false true true 8 Double 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_seagrass_buffer,Shape_Area,-1,-1")

# Process: Table To Excel (2)
arcpy.TableToExcel_conversion(Aids_seagrass_buffer, ATON_buffer_Seagrass_xls, "NAME", "CODE")

# Process: Dissolve
arcpy.Dissolve_management(Aids_seagrass_buffer, Aids_seagrass_buffer_dissolved__2_, "", "", "MULTI_PART",
"DISSOLVE_LINES")

# Process: Table To Excel (3)
arcpy.TableToExcel_conversion(Aids_seagrass_buffer_dissolved__2_, ATON_buffer_Seagrass_total_area_xls,
"NAME", "CODE")

# Process: Dissolve (5)
arcpy.Dissolve_management(Coral_Reefs__2_, Coral_Reefs_Dissolved, "", "", "MULTI_PART",
"DISSOLVE_LINES")

# Process: Select Layer By Location (2)
arcpy.SelectLayerByLocation_management(USCG_ATON__5_, "INTERSECT",
Johnsons_Seagrass_Critical_Habitat__2_, "", "NEW_SELECTION")

# Process: Copy Features
arcpy.CopyFeatures_management(USCG_ATON__6_, ATON_intersect_seagrass__5_, "", "0", "0", "0")

# Process: Select Layer By Location (3)
arcpy.SelectLayerByLocation_management(USCG_ATON__8_, "INTERSECT", WCMC_008_CoralReefs2010,
"100 Meters", "NEW_SELECTION")

# Process: Select Layer By Location (4)
arcpy.SelectLayerByLocation_management(USCG_ATON__8_, "INTERSECT",
Acropora_Critical_Habitat_dissolved, "", "ADD_TO_SELECTION")

# Process: Select Layer By Location (5)
arcpy.SelectLayerByLocation_management(USCG_ATON__9_, "INTERSECT",
ATON_in_Critical_Coral_Habitat__2_, "", "REMOVE_FROM_SELECTION")

# Process: Buffer
arcpy.Buffer_analysis(US_Coralreefs_dissolved, US_CoralReefs_100m, "100 Meters", "FULL", "ROUND",
"ALL", "")

# Process: Select Layer By Location (6)
arcpy.SelectLayerByLocation_management(ATON_in_coral_habitat, "INTERSECT", Pseudo_Coral_Habitat, "",
"NEW_SELECTION")

# Process: Select Layer By Attribute (3)
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arcpy.SelectLayerByAttribute_management(ATON_in_coral_habitat__5_, "NEW_SELECTION",
"AID_SUBTYPE = 'Fixed'")

# Process: Copy Features (9)
arcpy.CopyFeatures_management(ATON_in_coral_habitat__4_, fixed_intersect_coral, "", "0", "0", "0")

# Process: Calculate Field (3)
arcpy.CalculateField_management(fixed_intersect_coral, "ImpactRadius", "Sqr ( (0.16417322*
[PILING_COUNT])/3.14159265359)", "VB", "")

# Process: Buffer (2)
arcpy.Buffer_analysis(fixed_intersect_coral__2_, fixed_aids_coral_buffer, "ImpactRadius", "FULL", "ROUND",
"NONE", "")

# Process: Select Layer By Attribute (4)
arcpy.SelectLayerByAttribute_management(ATON_in_coral_habitat__5_, "NEW_SELECTION",
"AID_SUBTYPE = 'Floating'")

# Process: Copy Features (10)
arcpy.CopyFeatures_management(ATON_in_coral_habitat__3_, floating_intersect_coral, "", "0", "0", "0")

# Process: Calculate Field (4)
arcpy.CalculateField_management(floating_intersect_coral, "ImpactRadius",
"(!FINAL_MOORING_LENGTH_ft_! - float(!CHARTED_WTR_DEPTH!))*.3048", "PYTHON_9.3", "")

# Process: Buffer (5)
arcpy.Buffer_analysis(floating_intersect_seagrass__4_, floating_aids_coral_buffer, "ImpactRadius", "FULL",
"ROUND", "NONE", "")

# Process: Merge (3)
arcpy.Merge_management("Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer;Z:\\MP\\GIS\\Data\\CoralA
ids.gdb\\floating_aids_coral_buffer", Aids_coral_buffer, "AID_UID \"AID_UID\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,AID_UID,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,AID_UID,-1,-1;NAME \"NAME\" true true false
255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,NAME,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,NAME,-1,-1;Latitude \"Latitude\" true true false 8
Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,Latitude,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,Latitude,-1,-1;Longitude \"Longitude\" true true
false 8 Double 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,Longitude,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,Longitude,-1,-1;AID_TYPE \"AID_TYPE\" true
true false 255 Text 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,AID_TYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,AID_TYPE,-1,-1;AID_SUBTYPE
\"AID_SUBTYPE\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,AID_SUBTYPE,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,AID_SUBTYPE,-1,-1;DISTRICT \"DISTRICT\"
true true false 4 Long 0 0 ,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,DISTRICT,-1,-
1,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\floating_aids_coral_buffer,DISTRICT,-1,-1;DESCRIPTION_TYPE
\"DESCRIPTION_TYPE\" true true false 255 Text 0 0
,First,#,Z:\\MP\\GIS\\Data\\CoralAids.gdb\\fixed_aids_coral_buffer,DESCRIPTION_TYPE,-1,-
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```

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# Process: Table To Excel (5)
arcpy.TableToExcel_conversion(Aids_coral_buffer, ATON_buffer_coral_xls, "NAME", "CODE")

# Process: Dissolve (2)
arcpy.Dissolve_management(Aids_coral_buffer, Aids_coral_buffer_dissolved, "", "", "MULTI_PART",
"DISSOLVE_LINES")

# Process: Table To Excel (6)
arcpy.TableToExcel_conversion(Aids_coral_buffer_dissolved, ATON_buffer_coral_total_area_xls, "NAME",
"CODE")

# Process: Clip
arcpy.Clip_analysis(WCMC_008_CoralReefs2010__2_, Aids_coral_buffer, Coral_clipped_ATON_buffers, "")

# Process: Clip (2)
arcpy.Clip_analysis(Coral_clipped_ATON_buffers, Aids_coral_buffer, Coral_Impact_By_ATON, "")

# Process: Dissolve (3)
arcpy.Dissolve_management(Coral_Impact_By_ATON, Coral_Impact_By_ATON_Dissolved, "", "",
"MULTI_PART", "DISSOLVE_LINES")

# Process: Table To Excel (7)
arcpy.TableToExcel_conversion(Coral_Impact_By_ATON_Dissolved, Coral_Impact_By_ATON_Dissolved_xls,
"NAME", "CODE")
```

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```
# Process: Table To Excel (8)
arcpy.TableToExcel_conversion(Coral_Impact_By_ATON, Coral_Impact_By_ATON_xls, "NAME", "CODE")

# Process: Clip (3)
arcpy.Clip_analysis(Pseudo_Coral_Habitat__2_, Aids_coral_buffer, Coral_PseudoHabitat_clipped_ATON_buffers,
"")

# Process: Clip (4)
arcpy.Clip_analysis(Aids_coral_buffer, Coral_PseudoHabitat_clipped_ATON_buffers,
Coral_PseudoHabitat_Impact_By_ATON, "")

# Process: Dissolve (4)
arcpy.Dissolve_management(Coral_PseudoHabitat_Impact_By_ATON,
Coral_PseudoHabitat_Impact_By_ATON_Dissolved, "", "", "MULTI_PART", "DISSOLVE_LINES")

# Process: Table To Excel (4)
arcpy.TableToExcel_conversion(Coral_PseudoHabitat_Impact_By_ATON_Dissolved,
Coral_PseudoHabitat_Impact_By_ATON_Dissolved_xls, "NAME", "CODE")

# Process: Table To Excel (9)
arcpy.TableToExcel_conversion(Coral_PseudoHabitat_Impact_By_ATON,
Coral_PseudoHabitat_Impact_By_ATON_xls, "NAME", "CODE")
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Appendix C-1

USCG ATON in Critical *Halophila johnsonii* Habitat in Descending Order of Impact Area

Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
1	Biscayne Bay Buoy 7B	25.90150833	-80.1312561	Floating	94.56
2	Biscayne Bay Light 63	25.76156807	-80.18422699	Fixed	0.33
3	Indian River (South Section) Light 223	27.23031616	-80.20510101	Fixed	0.33
4	Biscayne Bay Daybeacon 12	25.89308929	-80.13833618	Fixed	0.16
5	Biscayne Bay Daybeacon 13	25.89024925	-80.13980103	Fixed	0.16
6	Biscayne Bay Daybeacon 25	25.85243034	-80.16934204	Fixed	0.16
7	Biscayne Bay Daybeacon 27	25.84324646	-80.17111969	Fixed	0.16
8	Biscayne Bay Daybeacon 36	25.81858826	-80.17507172	Fixed	0.16
9	Biscayne Bay Daybeacon 37	25.81794167	-80.17453003	Fixed	0.16
10	Biscayne Bay Daybeacon 4	25.91713715	-80.12648773	Fixed	0.16
11	Biscayne Bay Daybeacon 61	25.76542091	-80.18270874	Fixed	0.16
12	Biscayne Bay Light 3	25.91778946	-80.12554932	Fixed	0.16
13	Biscayne Bay Light 33	25.82698631	-80.1725235	Fixed	0.16
14	Biscayne Bay Light 55	25.77438927	-80.18308258	Fixed	0.16
15	Biscayne Creek Daybeacon 61	25.92117119	-80.1281662	Fixed	0.16
16	Biscayne Creek Daybeacon 63	25.92000389	-80.12731171	Fixed	0.16
17	Dodge Island Turning Basin Daybeacon B	25.77173615	-80.17951202	Fixed	0.16
18	Fishermans Channel Light 18	25.77303123	-80.18167877	Fixed	0.16
19	Fishermans Channel Light 7	25.76457405	-80.15370178	Fixed	0.16
20	Fishermans Channel Light 9	25.76494026	-80.16088104	Fixed	0.16
21	Flagler Monument Daybeacon 2	25.7847023	-80.15042877	Fixed	0.16
22	Hobe Sound Daybeacon 35	27.04418755	-80.11226654	Fixed	0.16
23	Hobe Sound Light 32	27.05389786	-80.11940002	Fixed	0.16
24	Indian River (South Section) Daybeacon 225	27.21882439	-80.19847107	Fixed	0.16
25	Lummus Island Turning Basin Light B	25.76490211	-80.16622925	Fixed	0.16
26	Lummus Island Turning Basin Light E	25.76805305	-80.17047119	Fixed	0.16
27	Miami Main Channel Light 15	25.76437569	-80.1373291	Fixed	0.16
28	Biscayne Bay Shoal Daybeacon	25.77110481	-80.18164825	Fixed	0.16
29	Biscayne Bay Daybeacon 11	25.89563751	-80.13569641	Fixed	0.16
30	Biscayne Bay Daybeacon 15	25.88270187	-80.14549255	Fixed	0.16
31	Biscayne Bay Daybeacon 16	25.87922096	-80.14910889	Fixed	0.16
32	Biscayne Bay Daybeacon 2	25.91833687	-80.12688446	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
33	Biscayne Bay Daybeacon 20	25.86336708	-80.16133118	Fixed	0.16
34	Biscayne Bay Daybeacon 21	25.85885239	-80.16379547	Fixed	0.16
35	Biscayne Bay Daybeacon 22	25.8559761	-80.16703796	Fixed	0.16
36	Biscayne Bay Daybeacon 24	25.85342216	-80.1688385	Fixed	0.16
37	Biscayne Bay Daybeacon 28	25.83827209	-80.17228699	Fixed	0.16
38	Biscayne Bay Daybeacon 29	25.83785057	-80.17173004	Fixed	0.16
39	Biscayne Bay Daybeacon 31	25.83226776	-80.17208099	Fixed	0.16
40	Biscayne Bay Daybeacon 34	25.8265152	-80.17319489	Fixed	0.16
41	Biscayne Bay Daybeacon 35	25.82252502	-80.17360687	Fixed	0.16
42	Biscayne Bay Daybeacon 39	25.81457138	-80.1752243	Fixed	0.16
43	Biscayne Bay Daybeacon 43	25.80171776	-80.17832184	Fixed	0.16
44	Biscayne Bay Daybeacon 44	25.79785919	-80.17982483	Fixed	0.16
45	Biscayne Bay Daybeacon 46	25.7963028	-80.18028259	Fixed	0.16
46	Biscayne Bay Daybeacon 47	25.79298973	-80.18086243	Fixed	0.16
47	Biscayne Bay Daybeacon 57	25.77200699	-80.1820755	Fixed	0.16
48	Biscayne Bay Daybeacon 6	25.90737724	-80.12734222	Fixed	0.16
49	Biscayne Bay Daybeacon 6A	25.90413857	-80.12987518	Fixed	0.16
50	Biscayne Bay Daybeacon 8	25.90018082	-80.13282013	Fixed	0.16
51	Biscayne Bay Light 18	25.87101173	-80.15548706	Fixed	0.16
52	Biscayne Bay Light 23	25.85404205	-80.16741943	Fixed	0.16
53	Biscayne Bay Light 45	25.79693794	-80.1794281	Fixed	0.16
54	Biscayne Bay Light 48	25.79297066	-80.18174744	Fixed	0.16
55	Biscayne Bay Light 49	25.79151535	-80.18093109	Fixed	0.16
56	Biscayne Bay Light 5	25.90912819	-80.12550354	Fixed	0.16
57	Biscayne Bay Light 64	25.76036835	-80.18513489	Fixed	0.16
58	Biscayne Bay Light 9	25.899683	-80.13264465	Fixed	0.16
59	Biscayne Creek Daybeacon 59	25.9237709	-80.1295166	Fixed	0.16
60	Biscayne Creek Light 60	25.92233849	-80.12994385	Fixed	0.16
61	Dodge Island Turning Basin Daybeacon A	25.77139664	-80.1788559	Fixed	0.16
62	Fishermans Channel Daybeacon 16	25.77330971	-80.18063354	Fixed	0.16
63	Fishermans Channel Light 11	25.76922417	-80.17040253	Fixed	0.16
64	Fishermans Channel Light 13	25.770401	-80.17303467	Fixed	0.16
65	Fishermans Channel Light 15	25.77194977	-80.17650604	Fixed	0.16
66	Fishermans Channel Light 17	25.7725029	-80.18032837	Fixed	0.16
67	Fishermans Channel Light 3	25.76442146	-80.14562988	Fixed	0.16
68	Fishermans Channel Light 5	25.76452827	-80.15079498	Fixed	0.16
69	Hobe Sound Daybeacon 31	27.05527306	-80.11920929	Fixed	0.16
70	Hobe Sound Daybeacon 33	27.05356407	-80.11846161	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
71	Hobe Sound Daybeacon 34	27.04999924	-80.1166153	Fixed	0.16
72	Hobe Sound Daybeacon 36	27.03824615	-80.10887146	Fixed	0.16
73	Hobe Sound Daybeacon 38	27.03616142	-80.10784149	Fixed	0.16
74	Hobe Sound Daybeacon 40	27.02887535	-80.10489655	Fixed	0.16
75	Hobe Sound Daybeacon 41	27.02256012	-80.10141754	Fixed	0.16
76	Hobe Sound Daybeacon 42	27.01502228	-80.09880066	Fixed	0.16
77	Hobe Sound Daybeacon 44	27.0076828	-80.09552765	Fixed	0.16
78	Hobe Sound Daybeacon 46	27.00102043	-80.09348297	Fixed	0.16
79	Hobe Sound Light 37	27.03742981	-80.10766602	Fixed	0.16
80	Hobe Sound Light 43	27.00803947	-80.09513092	Fixed	0.16
81	Indian River (South Section) Daybeacon 216	27.2737484	-80.2303772	Fixed	0.16
82	Indian River (South Section) Daybeacon 217	27.26726532	-80.22621918	Fixed	0.16
83	Indian River (South Section) Daybeacon 219	27.26076126	-80.22279358	Fixed	0.16
84	Indian River (South Section) Daybeacon 221	27.24058723	-80.21120453	Fixed	0.16
85	Lake Worth South Light 44	26.55429077	-80.04888153	Fixed	0.16
86	Lake Wyman Daybeacon 57	26.37291336	-80.07257843	Fixed	0.16
87	Lummus Island Turning Basin Light A	25.76501846	-80.16378784	Fixed	0.16
88	Lummus Island Turning Basin Light C	25.76502991	-80.16892242	Fixed	0.16
89	Miami Beach Channel Daybeacon 10	25.8465271	-80.13644409	Fixed	0.16
90	Miami Beach Channel Daybeacon 12	25.84450531	-80.1346817	Fixed	0.16
91	Miami Beach Channel Daybeacon 14	25.83909607	-80.13646698	Fixed	0.16
92	Miami Beach Channel Daybeacon 16	25.83238411	-80.13478088	Fixed	0.16
93	Miami Beach Channel Daybeacon 18	25.82652283	-80.13751984	Fixed	0.16
94	Miami Beach Channel Daybeacon 20	25.81942177	-80.14031219	Fixed	0.16
95	Miami Beach Channel Daybeacon 22	25.8155117	-80.14187622	Fixed	0.16
96	Miami Beach Channel Daybeacon 24	25.81325722	-80.14664459	Fixed	0.16
97	Miami Beach Channel Daybeacon 25	25.81217003	-80.14836121	Fixed	0.16
98	Miami Beach Channel Daybeacon 26	25.80596161	-80.1489563	Fixed	0.16
99	Miami Beach Channel Daybeacon 28	25.80269051	-80.15094757	Fixed	0.16
100	Miami Beach Channel Daybeacon 3	25.86445808	-80.14433289	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
101	Miami Beach Channel Daybeacon 30	25.79417801	-80.1481781	Fixed	0.16
102	Miami Beach Channel Daybeacon 4	25.86398697	-80.14505005	Fixed	0.16
103	Miami Beach Channel Daybeacon 5	25.86215782	-80.14452362	Fixed	0.16
104	Miami Beach Channel Daybeacon 6	25.86179924	-80.14518738	Fixed	0.16
105	Miami Beach Channel Daybeacon 8	25.85447121	-80.14696503	Fixed	0.16
106	Miami Beach Channel Light 11	25.84672928	-80.13336182	Fixed	0.16
107	Miami Beach Channel Light 2	25.86899376	-80.14470673	Fixed	0.16
108	Miami Main Channel Light 20	25.78393173	-80.17941284	Fixed	0.16
109	Miami River Channel Daybeacon 1	25.77099037	-80.18434143	Fixed	0.16
110	Miami River Channel Daybeacon 3	25.77033997	-80.18724823	Fixed	0.16
111	Miami Turning Basin Articulated Light A	25.78469849	-80.1802063	Fixed	0.16
112	Miami Turning Basin Articulated Light B	25.78638458	-80.18185425	Fixed	0.16
113	Sunset Harbor Channel Junction Daybeacon S	25.79417801	-80.1481781	Fixed	0.16

Appendix C-2

USCG ATON in Modified Critical Coral Habitat in Descending Order of Impact Area

Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
1	Punta Colorada Lighted Buoy 9	18.29315376	-65.27635193	Floating	15,981.14
2	Ala Wai Boat Harbor Entrance Lighted Buoy 2	21.27614212	-157.8461456	Floating	9,273.41
3	Bahia De San Juan Lighted Buoy 2	18.47216606	-66.12953186	Floating	8,442.16
4	Pago Pago Harbor Lighted Buoy 4	-14.27596378	-170.6790619	Floating	7,157.09
5	Fort Jefferson Lighted Buoy E	24.64999962	-82.96666718	Floating	7,109.50
6	Canal De La Mona East Shoal Lighted Buoy 2	17.89293098	-67.25469208	Floating	7,018.67
7	Punta Picua Lighted Buoy WR 2	18.44182396	-65.75999451	Floating	6,313.18
8	Fort Jefferson Lighted Buoy M	24.66666603	-82.76667023	Floating	6,313.18
9	ARRECIFE TOURMALINE LB 8 MPP	18.16121483	-67.34475708	Floating	6,221.36
10	Fort Jefferson Lighted Buoy O	24.61663628	-82.80000305	Floating	6,058.26
11	Fort Jefferson Lighted Buoy L	24.70000076	-82.76667023	Floating	5,974.46
12	Arrecife Tourmaline Lighted Buoy 8	18.16121483	-67.34475708	Floating	5,726.52
13	Biscayne National Park North Lighted Buoy N	25.6456871	-80.08948517	Floating	5,645.07
14	Kamalo Bay Reef Lighted Buoy 2	21.03163528	-156.8760834	Floating	5,641.22
15	Fort Jefferson Lighted Buoy H	24.71669388	-82.89994049	Floating	4,862.45
16	Tanapag Harbor Approach Lighted Buoy T	15.20319366	145.6746979	Floating	4,862.42
17	Boca De Cangrejos Lighted Buoy BC	18.46877861	-66.01087952	Floating	4,787.38
18	Mona Coast Guard Mooring Buoy	18.09057617	-67.94538879	Floating	4,652.03
19	Bahia De Guayanilla Lighted Buoy 2	17.96611214	-66.76212311	Floating	4,493.01
20	Apra Outer Harbor Entrance Lighted Buoy 1	13.45063019	144.6234283	Floating	4,307.15
21	Bajos Grampus South Lighted Buoy 2	18.25668716	-65.19504547	Floating	4,278.37
22	Fort Jefferson Buoy J	24.72554207	-82.832901	Floating	4,243.81
23	Fort Jefferson Buoy Q	24.58333397	-82.8666687	Floating	4,243.80
24	Fort Jefferson Buoy P	24.60000038	-82.83333588	Floating	4,243.78
25	Packet Rock Buoy 2	18.29662895	-64.88986969	Floating	3,932.97

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
26	MIAMI LB 10 DREDG	25.76000023	-80.12111664	Floating	3,887.19
27	Canal De La Mona East Shoal Lighted Buoy 4	18.00641632	-67.38336945	Floating	3,864.84
28	Apra Outer Harbor Entrance Lighted Buoy 2	13.45281315	144.6229858	Floating	3,862.76
29	Isla De Ramos Buoy 2	18.31057167	-65.59838867	Floating	3,798.61
30	Miami Main Channel Lighted Buoy 8	25.75860023	-80.11618042	Floating	3,731.65
31	Canal De La Mona East Shoal Lighted Buoy 6	18.08833504	-67.42327881	Floating	3,600.82
32	Fort Jefferson Lighted Buoy A	24.56666756	-82.90000153	Floating	3,536.27
33	Miami Main Channel Lighted Buoy 3	25.76107216	-80.09693146	Floating	3,408.92
34	Tinian Harbor Channel Lighted Buoy 1	14.95392704	145.6233368	Floating	3,366.99
35	Lake Worth Lighted Buoy LW	26.77266121	-80.01006317	Floating	3,346.14
36	Port Everglades Lighted Buoy 3	26.09242058	-80.09029388	Floating	3,222.31
37	Tinian Harbor Channel Lighted Buoy 2	14.95670986	145.6227417	Floating	3,166.18
38	West Gregerie Channel Lighted Buoy 2	18.30633354	-64.97628021	Floating	3,161.26
39	SAN JUAN COAST GUARD MOORING BUOY	18.46191025	-66.11475372	Floating	3,156.67
40	San Juan CG Mooring Buoy	18.46181679	-66.11478424	Floating	3,156.67
41	Miami Main Channel Lighted Buoy 4	25.75942802	-80.10645294	Floating	3,100.63
42	Sail Rock Lighted Buoy 1	18.28403664	-65.10852051	Floating	3,040.93
43	Key West Main Channel Lighted Buoy 3A	24.49764824	-81.80426025	Floating	3,040.93
44	Key West Main Channel Lighted Buoy 13	24.54286766	-81.81619263	Floating	3,039.12
45	Fort Jefferson Buoy N	24.63743973	-82.78659058	Floating	3,011.79
46	MIAMI LB 4 DREDG	25.75971603	-80.10666656	Floating	2,918.51
47	Southwest Cape Shoal Buoy 2	17.65043449	-64.90953064	Floating	2,822.16
48	Bahia De Guanica Entrance Lighted Buoy 2	17.92054176	-66.90415955	Floating	2,807.25
49	East Gregerie Channel Lighted Buoy WR1	18.31050301	-64.93453217	Floating	2,750.31
50	Key West Southwest Channel Lighted Buoy SW	24.4440403	-81.97982025	Floating	2,750.30
51	Red Point Buoy 1	18.30673218	-64.85964203	Floating	2,722.61
52	Kewalo Basin Lighted Buoy 2	21.2875309	-157.8621216	Floating	2,698.48
53	Bahia De San Juan Lighted Buoy 10	18.45905685	-66.12176514	Floating	2,698.48
54	Miami Main Channel Lighted Buoy 6	25.7584877	-80.11299133	Floating	2,693.93

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
55	Bahia De Tallaboa Lighted Buoy 1	17.96180153	-66.73822784	Floating	2,693.93
56	Bahia De Ponce Lighted Buoy 6	17.96320534	-66.62225342	Floating	2,618.37
57	Apra Outer Harbor Lighted Buoy 3	13.45395756	144.6540833	Floating	2,587.39
58	Mingo Rock Lighted Buoy 2	18.32304955	-64.80345154	Floating	2,582.94
59	Isla Palominos Lighted Buoy 2	18.35271454	-65.55882263	Floating	2,582.94
60	Fort Jefferson Lighted Buoy K	24.72553444	-82.79997253	Floating	2,474.29
61	Hillsboro Inlet Entrance Lighted Buoy HI	26.25219154	-80.07450867	Floating	2,474.28
62	Fort Jefferson Lighted Buoy I	24.7256031	-82.86668396	Floating	2,466.16
63	St Thomas Harbor Lighted Buoy 3	18.32184219	-64.92789459	Floating	2,455.13
64	Miami Anchorage Buoy B	25.77296829	-80.10256958	Floating	2,448.00
65	St Thomas Harbor Lighted Buoy 4	18.32250214	-64.9257431	Floating	2,401.90
66	Fort Jefferson Buoy G	24.69444466	-82.92221832	Floating	2,394.85
67	East Gregerie Channel Lighted Buoy 2	18.32061577	-64.93305206	Floating	2,367.96
68	Dixie Shoal Buoy 8	25.07765579	-80.31197357	Floating	2,329.20
69	St Thomas Harbor Entrance Lighted Buoy 2	18.30958176	-64.91786957	Floating	2,315.68
70	Bajos Largo Lighted Buoy 3	18.29491615	-65.58066559	Floating	2,315.67
71	Miami Main Channel Lighted Buoy 1	25.76315498	-80.08990479	Floating	2,315.67
72	Midway Channel Entrance Lighted Buoy 1	28.19831848	-177.3559723	Floating	2,315.67
73	Tennessee Reef East Lighted Buoy 18	24.79236031	-80.69339752	Floating	2,315.66
74	Bahia De San Juan Lighted Buoy 7	18.46666145	-66.1259079	Floating	2,268.14
75	Bahia De San Juan Lighted Buoy 9	18.46395302	-66.12398529	Floating	2,263.97
76	Bahia De San Juan Lighted Buoy 3	18.47161865	-66.12679291	Floating	2,263.96
77	Miami Main Channel Lighted Buoy 7	25.75521851	-80.11472321	Floating	2,263.96
78	Bajo Enmedio South Lighted Buoy 1	18.01246262	-67.20823669	Floating	2,245.66
79	Bahia De San Juan Lighted Buoy 13	18.45318985	-66.11000061	Floating	2,245.65
80	Punta Melones Shoal Buoy 1	17.99037552	-67.23427582	Floating	2,221.83
81	Dry Tortugas Southeast Channel Lighted Buoy 2	24.62319946	-82.82945251	Floating	2,216.97
82	Johnson Reef Lighted Buoy 1JR	18.36498833	-64.77374268	Floating	2,216.96
83	Radas Roosevelt Passage	18.16581535	-65.51676178	Floating	2,212.85

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
	Lighted Buoy 3				
84	Bahia De Guayanilla Lighted Buoy 3	17.96741104	-66.76486969	Floating	2,212.84
85	Fifteen-Foot Spot Lighted Buoy 1	18.34674454	-65.61549377	Floating	2,194.75
86	Tinian Harbor Channel Lighted Buoy 3	14.95799065	145.6263123	Floating	2,166.39
87	Tanapag Harbor Channel Lighted Buoy 2	15.22020626	145.6902466	Floating	2,166.38
88	Bahia De San Juan Lighted Buoy 14	18.45009613	-66.111763	Floating	2,166.38
89	Bajo Blake South Buoy 3	18.34038544	-65.53124237	Floating	2,121.14
90	Apra Outer Harbor Lighted Buoy 7	13.45131588	144.6586914	Floating	2,116.39
91	Bajo Amarillo Lighted Buoy 2	18.27776909	-65.27521515	Floating	2,094.67
92	West Gregerie Channel Lighted Buoy 3	18.320858	-64.97170258	Floating	2,066.98
93	Bahia De Mayaguez Entrance Lighted Buoy 4	18.2170372	-67.19740295	Floating	2,062.99
94	Miami Anchorage Buoy A	25.80574989	-80.09514618	Floating	2,039.00
95	Bahia De Guanica Buoy 5	17.94286156	-66.90745544	Floating	2,022.78
96	Miami Main Channel Lighted Buoy 9	25.75744247	-80.12000275	Floating	2,014.21
97	Diamond Head Reef Lighted Buoy 2	21.24683762	-157.8156586	Floating	2,014.21
98	Roosevelt Roads Harbor Channel Lighted Buoy 3	18.2030201	-65.61063385	Floating	1,966.01
99	Vieques Southwest Channel Lighted Buoy 2	18.16835403	-65.60639954	Floating	1,966.00
100	Key West Main Channel Lighted Buoy 7	24.51304245	-81.80574036	Floating	1,966.00
101	Miami Main Channel Lighted Buoy 2	25.76251602	-80.09754181	Floating	1,966.00
102	HAWK CHANNEL WR 57	24.53239441	-81.75894928	Floating	1,962.49
103	Bahia De San Juan Lighted Buoy 6	18.46727943	-66.12915039	Floating	1,918.39
104	Okino Reef Buoy 1	15.21194267	145.6958618	Floating	1,879.61
105	Roca Lavandera Del Oeste Buoy 5	18.27027512	-65.56781006	Floating	1,879.61
106	Bahia De Mayaguez Lighted Buoy 5	18.22045898	-67.17650604	Floating	1,875.16
107	Key West Main Channel Lighted Buoy 3	24.47005844	-81.80204773	Floating	1,871.37
108	Pearl Harbor Entrance Lighted Buoy 2	21.29916573	-157.9546661	Floating	1,871.36
109	Ko'Olina CG Mooring Buoy	21.33933258	-158.1371613	Floating	1,833.07
110	MIAMI LB 12 DREDG	25.76138306	-80.12471771	Floating	1,828.65
111	St Thomas Harbor Lighted Buoy 6	18.32838631	-64.92736053	Floating	1,828.65

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
112	Cabeza De Perro Lighted Buoy 7	18.22579193	-65.56154633	Floating	1,824.91
113	Radas Roosevelt Passage Lighted Buoy 1	18.18322563	-65.46998596	Floating	1,824.91
114	Fort Jefferson Buoy B	24.56665611	-82.93335724	Floating	1,802.35
115	Bahia De Tallaboa Buoy 2	17.96141052	-66.73579407	Floating	1,787.10
116	Bahia De San Juan Lighted Buoy 8	18.46380615	-66.1272583	Floating	1,782.74
117	Apra Outer Harbor Lighted Buoy 6	13.45382214	144.6589508	Floating	1,782.74
118	Rebecca Shoal Lighted Buoy 4	24.57877922	-82.59075165	Floating	1,779.05
119	Bahia De San Juan Lighted Buoy 5	18.46954155	-66.1271286	Floating	1,762.82
120	Coalbin Rock Buoy CB	24.45097733	-82.08826447	Floating	1,745.47
121	Punta Figueras Buoy 4	18.29124641	-65.59079742	Floating	1,741.72
122	Bajo Onaway Buoy 3	18.34615135	-65.6235733	Floating	1,741.72
123	Bahia De Ponce Lighted Buoy 4	17.94453621	-66.62866974	Floating	1,733.77
124	Roosevelt Roads Harbor Channel Lighted Buoy 2	18.20340347	-65.60663605	Floating	1,733.77
125	Barbers Point Harbor Entrance Channel Lighted Buoy 2	21.31538963	-158.1279602	Floating	1,733.77
126	Key West Main Channel Lighted Buoy 6	24.50931358	-81.80345154	Floating	1,733.76
127	Key West Main Channel Lighted Buoy 8	24.51647568	-81.80432129	Floating	1,733.76
128	Key West Southwest Channel Buoy C	24.46709442	-81.9298172	Floating	1,696.92
129	Kalihi Channel Lighted Buoy 3	21.29419899	-157.8977814	Floating	1,692.66
130	Kalihi Channel Lighted Buoy 4	21.29408646	-157.8965912	Floating	1,692.66
131	Honolulu Harbor Channel Lighted Buoy 1	21.29166985	-157.8740845	Floating	1,689.06
132	Radas Roosevelt Passage Lighted Buoy 4	18.17140579	-65.51854706	Floating	1,689.06
133	Cayo Largo Lighted Buoy 1A	18.31481552	-65.58865356	Floating	1,673.25
134	Cabezas Crespas Lighted Buoy 3	18.28079033	-65.25668335	Floating	1,673.25
135	Conch Reef Buoy 12	24.94957733	-80.45728302	Floating	1,656.35
136	Bahia De San Juan Lighted Buoy 11	18.45836067	-66.11712646	Floating	1,648.51
137	Key West Southwest Channel Buoy B	24.45848465	-81.94676208	Floating	1,645.38
138	Kaneohe Bay Channel Lighted Buoy 2	21.51459885	-157.8111115	Floating	1,644.95
139	Key West Main Channel Lighted Buoy 9	24.52855873	-81.81671906	Floating	1,644.95

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
140	Western Triangle Lighted Buoy 5	24.50872993	-81.80506134	Floating	1,644.95
141	Key West Southwest Channel Buoy 2	24.47472	-81.91345215	Floating	1,601.84
142	Bahia De Tallaboa Lighted Buoy 4	17.96554756	-66.73674774	Floating	1,601.42
143	Army Terminal Channel Lighted Buoy A	18.44865799	-66.10708618	Floating	1,586.03
144	Bajo Camaron Buoy 6	18.2856102	-65.26316071	Floating	1,566.02
145	Kaneohe Bay Warning Lighted Buoy A	21.44249916	-157.7841644	Floating	1,561.94
146	Bajo Grouper Buoy 5	18.2849617	-65.26642609	Floating	1,558.89
147	San Juan Harbor Anchorage F Lighted Buoy A	18.45022583	-66.11637878	Floating	1,558.89
148	Haleiwa Harbor Entrance Lighted Buoy 2	21.60307312	-158.1140747	Floating	1,558.48
149	Port Everglades Lighted Buoy 2	26.0948925	-80.09033203	Floating	1,558.47
150	Bahia De Ponce Lighted Buoy 5	17.95250511	-66.62926483	Floating	1,558.47
151	Fort Jefferson Lighted Buoy C	24.56666756	-82.96666718	Floating	1,558.47
152	Ala Wai Boat Harbor Entrance Lighted Buoy 1	21.27625465	-157.8469849	Floating	1,523.55
153	Honolulu Harbor Channel Lighted Buoy 6	21.29559708	-157.8701019	Floating	1,519.52
154	Miami Main Channel Lighted Buoy 5	25.75707817	-80.10900879	Floating	1,516.11
155	Christiansted Harbor Channel Lighted Buoy 1	17.7631588	-64.69655609	Floating	1,488.19
156	Canal Del Este Buoy 2	18.27679062	-65.2516098	Floating	1,481.67
157	Cabezas Puercas Buoy 4	18.28390121	-65.25502014	Floating	1,440.37
158	Puerto Arecibo Buoy 4	18.47795296	-66.70433807	Floating	1,440.37
159	Bahia De Guanica Buoy 9	17.95926094	-66.91059875	Floating	1,440.36
160	Apra Outer Harbor Lighted Buoy 5	13.45359135	144.6560211	Floating	1,436.45
161	Army Terminal Channel Lighted Buoy 2	18.44720078	-66.10980988	Floating	1,430.14
162	West Gregerie Channel Lighted Buoy 4	18.32132721	-64.95839691	Floating	1,430.13
163	Fort Jefferson Buoy D	24.60833359	-82.96666718	Floating	1,413.16
164	Manchas Exteriores Buoy 1	18.24126434	-67.21183014	Floating	1,399.65
165	Dry Tortugas Southwest Channel Buoy 1	24.61126328	-82.92734528	Floating	1,399.65
166	Apra Harbor Western Shoal Buoy WS	13.44988346	144.6539154	Floating	1,399.65
167	Bahia De Tallaboa Lighted Buoy 5	17.96999168	-66.73829651	Floating	1,392.53
168	Bahia De San Juan Lighted Buoy 4	18.46941566	-66.1293869	Floating	1,392.53

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
169	Kalihi Channel Entrance Lighted Buoy 1	21.28981018	-157.8985443	Floating	1,392.52
170	Graving Dock Channel Lighted Buoy 3	18.44560623	-66.09463501	Floating	1,389.57
171	Cayo Largo Buoy 1	18.33129311	-65.59129333	Floating	1,359.51
172	Puerto Arecibo Buoy 6	18.47894669	-66.70269775	Floating	1,349.58
173	Bahia De Guanica Buoy 7	17.95779991	-66.90906525	Floating	1,319.97
174	Pearl Harbor Entrance Lighted Buoy 1	21.29783821	-157.956955	Floating	1,316.23
175	Graving Dock Channel Lighted Buoy 4	18.44292259	-66.08972931	Floating	1,310.18
176	Crocker Reef Buoy 16	24.90826988	-80.52453613	Floating	1,284.23
177	Cabrita Point Lighted Buoy 1	18.32231522	-64.83031464	Floating	1,277.32
178	Kahului Harbor Lighted Buoy 8	20.89515114	-156.4737854	Floating	1,277.31
179	Bahia De Guanica Buoy 6	17.95613289	-66.9076767	Floating	1,274.57
180	Christiansted Harbor Channel Lighted Buoy 3	17.76063728	-64.69549561	Floating	1,271.36
181	Midway Channel Buoy 8	28.20991135	-177.3540649	Floating	1,242.63
182	Bahia De Guanica Buoy 3	17.93674088	-66.90855408	Floating	1,242.63
183	Puerto Arecibo Buoy 2	18.4785099	-66.70640564	Floating	1,242.62
184	Puerto Arecibo Buoy 1	18.47992706	-66.70497131	Floating	1,242.62
185	Punta Carenero Buoy 10	18.29344749	-65.27594757	Floating	1,242.57
186	Tinian Harbor Channel Lighted Buoy 4	14.95910454	145.6243134	Floating	1,239.00
187	Barbers Point Harbor Entrance Channel Lighted Buoy 3	21.31666756	-158.1292267	Floating	1,235.92
188	Puerto Nuevo Channel Lighted Buoy 3	18.43562698	-66.09693146	Floating	1,233.13
189	Bahia De Guayanilla Lighted Buoy 8	17.99198341	-66.76625824	Floating	1,233.12
190	San Juan Harbor Anchorage E Buoy B	18.44977951	-66.10150146	Floating	1,204.83
191	Key West Main Channel Lighted Buoy 12	24.53292465	-81.81502533	Floating	1,198.22
192	Agat Small Boat Harbor Entrance Lighted Buoy 1	13.36594677	144.6437073	Floating	1,192.00
193	Bajo Snapper Lighted Buoy 8	18.28935814	-65.27153015	Floating	1,164.10
194	Bahia De Guanica Buoy 8	17.95913315	-66.90795135	Floating	1,161.47
195	Bahia De Jobos Buoy 2	17.93127441	-66.27229309	Floating	1,158.41
196	HAWK CHANNEL WR 57	24.53239441	-81.75894928	Floating	1,158.40
197	Key West Main Channel North Spoil Bank Lighted Buoy A	24.52142906	-81.8166275	Floating	1,158.33
198	Bahia De Jobos Buoy 3	17.93166733	-66.2638855	Floating	1,152.29
199	Apra Outer Harbor Buoy 9	13.4483881	144.6600494	Floating	1,130.99

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
200	Miami Main Channel Lighted Buoy 11	25.75967026	-80.12541962	Floating	1,127.52
201	Honolulu Harbor Channel Lighted Buoy 2	21.29097557	-157.8726654	Floating	1,124.59
202	San Juan Harbor Anchorage E Buoy A	18.45393562	-66.10663605	Floating	1,089.00
203	Cayo Puerca Buoy 5	17.92496872	-66.2385025	Floating	1,086.02
204	WORK ORDER KW MAIN CHNL SPOIL BUOY A	24.52154922	-81.81653595	Floating	1,085.98
205	Bahia De Guayanilla Buoy 9	17.99161911	-66.77988434	Floating	1,059.48
206	Taema Bank Lighted Buoy 1	-14.32387638	-170.6745758	Floating	1,053.28
207	Miami Main Channel Lighted Buoy 10	25.75969505	-80.1211319	Floating	1,053.19
208	Puerto Nuevo Channel Lighted Buoy 5	18.43976784	-66.08978271	Floating	1,050.71
209	Army Terminal Channel Lighted Buoy 5	18.44095993	-66.10800171	Floating	1,050.71
210	Kalihi Channel Lighted Buoy 6	21.29919434	-157.8959351	Floating	1,021.31
211	Key West Southwest Channel Buoy 4	24.49240303	-81.89045715	Floating	1,018.84
212	Midway Channel Buoy 7	28.21037674	-177.3557434	Floating	990.31
213	Bahia De Mayaguez Lighted Buoy 6	18.21605301	-67.16373444	Floating	987.07
214	Midway Channel Buoy 3	28.20252228	-177.3552551	Floating	956.60
215	Agat Harbor Entrance Lighted Buoy AG	13.36768818	144.6418762	Floating	950.71
216	Army Terminal Channel Lighted Buoy 6	18.43722534	-66.10921478	Floating	948.27
217	Bahia De Guanica Lighted Buoy 4	17.93691444	-66.90698242	Floating	948.26
218	Punta Cabras Buoy 14	18.30020332	-65.2808609	Floating	948.26
219	Key West Southwest Channel Buoy 3	24.4840641	-81.90434265	Floating	923.47
220	Graving Dock Channel Lighted Buoy 1	18.44848251	-66.10266113	Floating	915.29
221	Bahia De Ponce Lighted Buoy 7	17.97128487	-66.62709808	Floating	915.29
222	East Gregerie Channel Lighted Buoy 3	18.3302803	-64.94372559	Floating	915.28
223	Puerto Nuevo Channel Lighted Buoy 1	18.43223763	-66.10240173	Floating	915.28
224	Kahului Harbor Lighted Buoy 6	20.89698601	-156.4747314	Floating	915.28
225	Apra Outer Harbor Lighted Buoy 8	13.45253849	144.6600494	Floating	890.93
226	Kaunakakai Harbor Lighted Buoy 3	21.07759666	-157.0325928	Floating	887.86
227	Honolulu Harbor Channel Lighted Buoy 5	21.29764175	-157.8706512	Floating	887.85

Appendix C-2

Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
228	Miami Main Channel Lighted Buoy 12	25.76099014	-80.12467957	Floating	887.85
229	Army Terminal Channel Turning Basin Lighted Buoy 9	18.4324646	-66.1053009	Floating	851.07
230	Midway Channel Entrance Buoy 2	28.19833755	-177.3532867	Floating	822.42
231	Sampan Channel Entrance Lighted Buoy 2	21.46932411	-157.7771149	Floating	796.80
232	Cabras Island Channel Lighted Buoy 5	13.45679951	144.6638031	Floating	793.90
233	Midway Channel Buoy 4	28.2023735	-177.3539429	Floating	791.73
234	Graving Dock Channel Lighted Buoy 2	18.44450378	-66.09527588	Floating	789.19
235	Christiansted Harbor Channel Lighted Buoy 4	17.76025009	-64.69644928	Floating	736.97
236	Army Terminal Channel Lighted Buoy 3	18.44718742	-66.10864258	Floating	729.66
237	Bahia De Tallaboa Lighted Buoy 6	17.97620583	-66.73628998	Floating	729.66
238	Sampan Channel Junction Buoy S	21.44833374	-157.7947235	Floating	707.94
239	Key West Main Channel Lighted Bell Buoy 2	24.46845245	-81.79989624	Floating	700.77
240	Kaneohe Bay Channel Buoy 4	21.50523949	-157.8223877	Floating	679.47
241	Christiansted Harbor Channel Buoy 8	17.75797462	-64.69670868	Floating	674.79
242	Kaunakakai Harbor Lighted Buoy 2	21.07624054	-157.0312347	Floating	668.41
243	Tinian Harbor Channel Buoy 6	14.96194649	145.6230621	Floating	651.61
244	Honolulu Harbor Channel Buoy 3	21.29508591	-157.8721771	Floating	651.61
245	Bahia De Guayanilla Buoy 7	17.9862442	-66.77468872	Floating	651.60
246	Bahia De Guayanilla Lighted Buoy 6	17.98671722	-66.76725769	Floating	648.97
247	Roosevelt Roads Harbor Channel Lighted Buoy 7	18.21419334	-65.62187195	Floating	644.73
248	Kewalo Basin Lighted Buoy 1	21.28782272	-157.8625946	Floating	624.32
249	Kaunakakai Harbor Buoy 4	21.0784626	-157.0306549	Floating	624.31
250	Haleiwa Harbor Buoy 3	21.59954262	-158.108017	Floating	619.82
251	Roosevelt Roads Harbor Channel Lighted Buoy 6	18.21596146	-65.61976624	Floating	617.59
252	West Gregerie Channel Lighted Buoy 5	18.32725143	-64.95568848	Floating	617.58
253	Christiansted Harbor Channel Lighted Buoy 6	17.75909996	-64.6958847	Floating	591.02
254	KAILUA BAY SECURITY ZONE BUOY	21.42194366	-157.7416687	Floating	591.02
255	Army Terminal Channel Lighted Buoy 7	18.43503952	-66.10774231	Floating	591.02

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
256	Kahului Harbor Buoy 5	20.89998055	-156.4714966	Floating	545.95
257	Gregerie Preferred Channel Lighted Buoy GC	18.33167267	-64.94682312	Floating	518.64
258	Bahia De Mayaguez Buoy 8	18.21563148	-67.16133118	Floating	514.85
259	Kaneohe Bay Channel Buoy 3	21.50968361	-157.8160858	Floating	504.68
260	Sampan Channel Buoy 4	21.46224022	-157.7834778	Floating	492.62
261	Haleiwa Harbor Buoy 4	21.59914398	-158.1089172	Floating	492.62
262	Bahia De Guayanilla Lighted Buoy 5	17.98093796	-66.77101135	Floating	466.98
263	Round Reef Northeast Junction Lighted Buoy RR	17.75683022	-64.69591522	Floating	466.98
264	Kalihi Channel Lighted Buoy 5	21.2994957	-157.8970032	Floating	447.45
265	Bahia De Guanica Buoy 10	17.96022797	-66.91112518	Floating	443.93
266	Christiansted Harbor Channel Lighted Buoy 14	17.75045586	-64.70096588	Floating	421.45
267	Kahului Harbor Lighted Buoy 12	20.89429092	-156.4703217	Floating	399.56
268	Punta Carenero Buoy 12	18.29611778	-65.27787018	Floating	399.56
269	Kaunakakai Harbor Buoy 5	21.0832634	-157.0294647	Floating	383.53
270	Bahia De Mayaguez Buoy 10	18.21668243	-67.15962219	Floating	378.25
271	Kaneohe Bay Channel Buoy 26	21.43716049	-157.7866669	Floating	333.62
272	Kewalo Basin Lighted Buoy 3	21.28981209	-157.8611603	Floating	285.03
273	Hickam Harbor Channel Buoy 1	21.30352211	-157.9530182	Floating	285.02
274	Looe Key Light 24 target position	24.54680252	-81.40258026	Floating	280.48
275	Christiansted Harbor Channel Lighted Buoy 12	17.75460052	-64.70032501	Floating	245.46
276	Honolulu Harbor Channel Buoy 4	21.29432869	-157.8708801	Floating	232.92
277	Christiansted Harbor Channel Buoy 15	17.74877548	-64.6993866	Floating	230.18
278	Army Terminal Channel Lighted Buoy 4	18.44181252	-66.10949707	Floating	228.82
279	Kewalo Basin Lighted Buoy 4	21.28980064	-157.8604584	Floating	201.11
280	Kaneohe Bay Warning Buoy C	21.43499947	-157.7666626	Floating	198.57
281	Kewalo Basin Lighted Buoy 6	21.29183578	-157.8590088	Floating	186.08
282	Kaneohe Bay Utility Channel Buoy 2	21.45228767	-157.7833099	Floating	95.44
283	Hickam Harbor Channel Buoy 5	21.30971909	-157.9536133	Floating	85.18
284	Marvin D Adams Waterway Lighted Buoy 2	25.13674736	-80.39459991	Floating	84.35
285	Kaneohe Bay Utility Channel Buoy 5	21.44938087	-157.780838	Floating	74.72

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
286	TEMP ANGEL FISH 6	25.33247566	-80.2539444	Floating	73.17
287	Pearl Harbor Buoy 3	21.30864143	-157.9629059	Floating	32.66
288	Bahia De Guayanilla Entrance Range Rear Light	17.98526955	-66.76412964	Fixed	0.82
289	Christiansted Harbor Channel Light 9	17.75631142	-64.69843292	Fixed	0.82
290	Bahia De San Juan Range Rear Light	18.45510483	-66.12848663	Fixed	0.82
291	Christiansted Harbor Channel Light 7	17.75716972	-64.69445801	Fixed	0.82
292	Christiansted Harbor Channel Light 11	17.75563049	-64.69910431	Fixed	0.82
293	Graving Dock Channel Turning Basin Light 5	18.44313049	-66.08618927	Fixed	0.82
294	Bahia De San Juan Range Front Light	18.45708847	-66.12844849	Fixed	0.82
295	Bahia De San Juan Range Front Passing Light	18.45708084	-66.12845612	Fixed	0.82
296	Christiansted Harbor Channel Light 13	17.75094032	-64.69906616	Fixed	0.82
297	Safe Harbor Channel Light 2	24.54254532	-81.73162842	Fixed	0.66
298	New Ground Rocks Light	24.66659927	-82.44416046	Fixed	0.66
299	Midway Channel Range Rear Daybeacon	28.23596382	-177.3547974	Fixed	0.66
300	Dry Tortugas Southeast Channel Light 1	24.59363937	-82.87374115	Fixed	0.66
301	Key West Main Channel Range Front Light	24.53734207	-81.80631256	Fixed	0.66
302	Sand Key Light	24.45581627	-81.87731171	Fixed	0.66
303	Cruz Bay Light	18.33265877	-64.7984848	Fixed	0.66
304	Carysfort Reef Light	25.22691345	-80.20922852	Fixed	0.66
305	Basin Hills Light 31bh	25.21852875	-80.29951477	Fixed	0.49
306	Kalihi Channel Light 7	21.30479813	-157.8964996	Fixed	0.49
307	Kalihi Channel Light 11	21.30905724	-157.8948059	Fixed	0.49
308	Kalihi Channel Light 8	21.30450058	-157.8951416	Fixed	0.49
309	Maunalua Bay Light 1	21.27086258	-157.7155914	Fixed	0.49
310	Kalihi Channel Light 10	21.30814743	-157.8936768	Fixed	0.49
311	Midway Channel Range Front Daybeacon	28.23100662	-177.3547821	Fixed	0.49
312	Las Croabas Daybeacon 2	18.36378479	-65.62216187	Fixed	0.16
313	Davis Reef Light 14	24.92577934	-80.50268555	Fixed	0.16
314	Barbers Point Harbor Entrance Channel Light 4	21.31876373	-158.1245728	Fixed	0.16
315	Ocean Reef Harbor Entrance Light 2	25.30857277	-80.26754761	Fixed	0.16
316	Largo Sound Channel Daybeacon 10	25.10070419	-80.41277313	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
317	Elliott Key Daybeacon 14	25.46321106	-80.1679306	Fixed	0.16
318	Whale Harbor Channel Daybeacon 4	24.93317604	-80.59859467	Fixed	0.16
319	Kaneohe Bay Channel Daybeacon 15	21.47034836	-157.8261719	Fixed	0.16
320	Sampan Channel Daybeacon 8	21.45012665	-157.7928772	Fixed	0.16
321	Snake Creek Daybeacon 7A	24.94650841	-80.58421326	Fixed	0.16
322	Kaneohe Bay Channel Light 22	21.44578743	-157.7939301	Fixed	0.16
323	West Washerwoman Daybeacon 53	24.55150414	-81.58488464	Fixed	0.16
324	Pacific Reef Light	25.37098503	-80.14205933	Fixed	0.16
325	Stock Island Approach Channel Light 32	24.47470856	-81.74214935	Fixed	0.16
326	Largo Sound Channel Light 2	25.09622955	-80.39737701	Fixed	0.16
327	Nine-Foot Shoal Light	24.56918526	-81.55187988	Fixed	0.16
328	Pulaski Shoal Light	24.69333839	-82.772995	Fixed	0.16
329	Pearl Harbor Light 6	21.31869888	-157.9651184	Fixed	0.16
330	Biscayne Channel Light 1	25.64480591	-80.1339798	Fixed	0.16
331	Fort Jefferson West Channel Daybeacon 9	24.62532806	-82.87550354	Fixed	0.16
332	Hawk Channel Light 57	24.53224754	-81.75897217	Fixed	0.16
333	Largo Sound Channel Daybeacon 3	25.09766579	-80.40267181	Fixed	0.16
334	Angelfish Creek Daybeacon 3A	25.32930374	-80.25128937	Fixed	0.16
335	Soldier Key Daybeacon 4	25.57029343	-80.13253021	Fixed	0.16
336	Port Everglades Light 5	26.09261513	-80.1023941	Fixed	0.16
337	Hickam Harbor Channel Daybeacon 3	21.30711365	-157.9529877	Fixed	0.16
338	Fort Jefferson East Channel Daybeacon 7	24.63267708	-82.8707428	Fixed	0.16
339	Sister Creek Light 2	24.68737411	-81.08654785	Fixed	0.16
340	Stock Island Approach Channel Daybeacon 2	24.50856781	-81.73149872	Fixed	0.16
341	Elliott Key Light 16	25.44671822	-80.17021179	Fixed	0.16
342	Sister Creek Daybeacon 6	24.69030952	-81.08807373	Fixed	0.16
343	Triumph reef lt temp	25.47944641	-80.11520386	Fixed	0.16
344	Dry Tortugas Southeast Middle Ground Daybeacon	24.64741707	-82.8706665	Fixed	0.16
345	Fort Jefferson East Channel Daybeacon 5	24.63410378	-82.87152863	Fixed	0.16
346	Kaneohe Bay Channel Light 14	21.47308731	-157.8289795	Fixed	0.16
347	Hickam Harbor Channel Daybeacon 4	21.30705833	-157.9520721	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
348	Bird Key Harbor Daybeacon 2BK	24.62521553	-82.88147736	Fixed	0.16
349	Boca Chica Channel Daybeacon 5	24.55281448	-81.72294617	Fixed	0.16
350	Tavernier Creek Daybeacon 2	24.99077415	-80.52407074	Fixed	0.16
351	Snake Creek Daybeacon 4A	24.94335175	-80.58342743	Fixed	0.16
352	Kualoa Point Range Rear Light	21.49760437	-157.833252	Fixed	0.16
353	Kahului Harbor Entrance Breakwater Light 3	20.90065575	-156.4715118	Fixed	0.16
354	Rupert Rock Daybeacon	18.32814407	-64.92663574	Fixed	0.16
355	Hen And Chickens Shoal Light 40	24.93296814	-80.54871368	Fixed	0.16
356	Long Key Light 44	24.79673576	-80.78351593	Fixed	0.16
357	Biscayne Channel Daybeacon 8	25.65359116	-80.15279388	Fixed	0.16
358	Fort Jefferson East Channel Daybeacon 9	24.63107491	-82.87007904	Fixed	0.16
359	West Washerwoman Daybeacon 51	24.55571175	-81.56395721	Fixed	0.16
360	Fat Deer Key Daybeacon 48	24.69166946	-81.02480316	Fixed	0.16
361	Largo Sound Channel Daybeacon 6	25.09895325	-80.40835571	Fixed	0.16
362	Elliott Key Light 20	25.38559723	-80.19159698	Fixed	0.16
363	Looe Key Light 24	24.54680252	-81.40258026	Fixed	0.16
364	Mosquito Bank Light 2	25.07668304	-80.42727661	Fixed	0.16
365	Sand Key Channel Daybeacon 2	24.46115685	-81.8799057	Fixed	0.16
366	Dry Tortugas Southwest Channel Daybeacon 4	24.62805939	-82.89810181	Fixed	0.16
367	Fort Jefferson East Channel Daybeacon 3	24.63544846	-82.87258911	Fixed	0.16
368	Kaneohe Bay Channel Daybeacon 12	21.48739815	-157.8325348	Fixed	0.16
369	Western Dry Rocks Daybeacon K	24.44638824	-81.92683411	Fixed	0.16
370	Fort Jefferson West Channel Daybeacon 3	24.62804222	-82.87981415	Fixed	0.16
371	Pacific Reef Daybeacon 3	25.37365723	-80.15983582	Fixed	0.16
372	Bache Shoal Daybeacon 13	25.47776985	-80.15375519	Fixed	0.16
373	Tavernier Creek Daybeacon 1	24.99064827	-80.52427673	Fixed	0.16
374	Sister Creek Daybeacon 8	24.69159126	-81.08815765	Fixed	0.16
375	Largo Sound Channel Daybeacon 19	25.12113762	-80.40271759	Fixed	0.16
376	Sister Creek Daybeacon 3	24.68862152	-81.08763123	Fixed	0.16
377	Largo Sound Channel Daybeacon 13	25.10629845	-80.41204071	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
378	Government Cut Range Rear Light	25.75035858	-80.10148621	Fixed	0.16
379	Kaneohe Bay Utility Channel Daybeacon 3	21.45267296	-157.782486	Fixed	0.16
380	Agana Small Boat Basin Approach Light 1	13.4822998	144.7517395	Fixed	0.16
381	Whale Harbor Channel Daybeacon 9	24.93873596	-80.61013794	Fixed	0.16
382	Agana Small Boat Basin Approach Light 2	13.48227692	144.7534027	Fixed	0.16
383	Ceasar Creek Dbn 10	25.38398743	-80.21009827	Fixed	0.16
384	Hillsboro Inlet Entrance Light 4	26.25694847	-80.08020782	Fixed	0.16
385	Caesar Creek Daybeacon 10	25.38398552	-80.21008301	Fixed	0.16
386	Turtle Harbor Daybeacon 1	25.28439713	-80.20787811	Fixed	0.16
387	Whale Harbor Channel Daybeacon 6	24.93722153	-80.60569	Fixed	0.16
388	Pacific Reef Daybeacon 2	25.37505531	-80.15367889	Fixed	0.16
389	Bahia Honda Key Light 49A	24.62498474	-81.23567963	Fixed	0.16
390	Newfound Harbor Keys Light 50	24.61316109	-81.39402008	Fixed	0.16
391	Snake Creek Daybeacon 3	24.94165802	-80.58188629	Fixed	0.16
392	Bache Shoal Light 11bs	25.48660851	-80.14894867	Fixed	0.16
393	Hillsboro Inlet Daybeacon 3	26.25543213	-80.08011627	Fixed	0.16
394	Largo Sound Channel Daybeacon 7	25.09879684	-80.40841675	Fixed	0.16
395	Miami Main Channel Entrance Range Front Light Temp	25.75177193	-80.12732697	Fixed	0.16
396	Key Largo Daybeacon 37	25.03798485	-80.42747498	Fixed	0.16
397	Pirates Cove Daybeacon 4	24.61462021	-81.5082016	Fixed	0.16
398	Angelfish Creek Daybeacon 5	25.33340645	-80.2556076	Fixed	0.16
399	Coakley Bay Light 1	17.76636124	-64.64458466	Fixed	0.16
400	Safe Harbor Channel Light 3	24.5466404	-81.73316956	Fixed	0.16
401	Biscayne Channel Daybeacon 4	25.65186501	-80.14359283	Fixed	0.16
402	Western Sambos Shoal Daybeacon	24.48311996	-81.70310211	Fixed	0.16
403	Largo Sound Channel Daybeacon 21	25.12397385	-80.40010834	Fixed	0.16
404	Safe Harbor Channel Daybeacon 5	24.55547905	-81.73491669	Fixed	0.16
405	Angelfish Creek Daybeacon 3	25.32889748	-80.25093842	Fixed	0.16
406	Miami Main Channel Entrance Range Front Light	25.75171089	-80.12741089	Fixed	0.16
407	Turtle Harbor Daybeacon 6	25.27241898	-80.22795105	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
408	Tavernier Key Light 2	25.00381851	-80.48258209	Fixed	0.16
409	Sombrero Key Light	24.62784386	-81.11080933	Fixed	0.16
410	Boca Chica Channel Daybeacon 4	24.55248642	-81.72258759	Fixed	0.16
411	Heeia Kea Small Boat Harbor Light 2	21.44818115	-157.8094025	Fixed	0.16
412	Pirates Cove Daybeacon 1	24.60860825	-81.51126862	Fixed	0.16
413	Newfound Harbor Channel Entrance Light 2	24.6189518	-81.40708923	Fixed	0.16
414	Whale Harbor Channel Daybeacon 4A	24.93412781	-80.60073853	Fixed	0.16
415	Carysfort Reef Light (Abandoned)	25.22187042	-80.21141815	Fixed	0.16
416	Kahului Harbor Entrance Breakwater Light 4	20.90032387	-156.4741211	Fixed	0.16
417	Eastern Sambos Shoal Daybeacon	24.49189758	-81.66343689	Fixed	0.16
418	Largo Sound Channel Daybeacon 14	25.10756111	-80.41070557	Fixed	0.16
419	Rebecca Shoal Light (Abandoned)	24.57902336	-82.58521271	Fixed	0.16
420	Tennessee Reef Light	24.74607849	-80.78235626	Fixed	0.16
421	Kaneohe Bay Utility Channel Light 4	21.44957542	-157.7815247	Fixed	0.16
422	Old Rhodes Key Light 22	25.34812737	-80.20560455	Fixed	0.16
423	Key Largo Daybeacon 33	25.13870811	-80.33360291	Fixed	0.16
424	Bird Key Harbor Daybeacon 5BK	24.62037468	-82.87974548	Fixed	0.16
425	Fort Jefferson East Channel Daybeacon 8	24.63071823	-82.87129974	Fixed	0.16
426	Bowles Bank Light 8	25.50726318	-80.14559174	Fixed	0.16
427	Cosgrove Shoal Light	24.457901	-82.18504333	Fixed	0.16
428	Western Sambos West Shoal Daybeacon	24.48003387	-81.7193985	Fixed	0.16
429	Biscayne Channel Light 2	25.64723969	-80.13451385	Fixed	0.16
430	Key Largo Daybeacon 39	25.00963783	-80.45787048	Fixed	0.16
431	Pohakuloa Point Light	20.92905045	-156.9876404	Fixed	0.16
432	Largo Sound Channel Daybeacon 20	25.12383461	-80.39993286	Fixed	0.16
433	Fowey Rocks Light	25.59062386	-80.09673309	Fixed	0.16
434	Whale Harbor Light 1	24.93108559	-80.59533691	Fixed	0.16
435	Pacific Reef Daybeacon 4	25.38079071	-80.17861176	Fixed	0.16
436	Bahia De Ponce Range Front Light	17.97391701	-66.62187958	Fixed	0.16
437	Government Cut Range Front Light	25.75306892	-80.10800934	Fixed	0.16
438	Caesar Creek Daybeacon 11	25.38375664	-80.21530914	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
439	Turtle Harbor West Shoal Daybeacon 2	25.32280159	-80.21078491	Fixed	0.16
440	Puerto Nuevo Channel Range Front Light	18.44111633	-66.08621979	Fixed	0.16
441	Caesar Creek Daybeacon 13	25.38373756	-80.21768188	Fixed	0.16
442	Bajos Chinchorro Del Sur Light	18.23424149	-65.51924896	Fixed	0.16
443	Channel Five Daybeacon 4	24.82738495	-80.7728653	Fixed	0.16
444	Largo Sound Channel Daybeacon 8	25.10004425	-80.41234589	Fixed	0.16
445	Elbow Reef Light 6	25.1445446	-80.25829315	Fixed	0.16
446	Kaneohe Bay Channel Light 18	21.46102524	-157.8218689	Fixed	0.16
447	White Shoal North Daybeacon 7	24.64835739	-82.89295959	Fixed	0.16
448	West Turtle Shoal Daybeacon 47	24.70010567	-80.96899414	Fixed	0.16
449	Pirates Cove Daybeacon 6	24.62027168	-81.50925446	Fixed	0.16
450	Snake Creek Light 2	24.94137383	-80.58107758	Fixed	0.16
451	Whale Harbor Channel Daybeacon 8	24.93840408	-80.60764313	Fixed	0.16
452	Boca Chica Channel Daybeacon 2	24.54784775	-81.724823	Fixed	0.16
453	Angelfish Creek Daybeacon 4	25.33162498	-80.25315857	Fixed	0.16
454	Pearl Harbor Light 5	21.31516457	-157.96698	Fixed	0.16
455	Pelican Key Daybeacon 55	24.55374336	-81.62071991	Fixed	0.16
456	Middle Ground Daybeacon 3	24.48286057	-81.88149261	Fixed	0.16
457	Bear Cut Daybeacon 2	25.72610092	-80.13378906	Fixed	0.16
458	Pirates Cove Daybeacon 3	24.61282349	-81.50933075	Fixed	0.16
459	Key Largo Daybeacon 32A	25.14743423	-80.35324097	Fixed	0.16
460	Sampan Channel Daybeacon 7	21.45372009	-157.7887115	Fixed	0.16
461	Whale Harbor Channel Daybeacon 5	24.9353714	-80.60336304	Fixed	0.16
462	Boca Chica Channel Light 1	24.54631424	-81.72624207	Fixed	0.16
463	Temp Miami Entrance RRL	25.74992943	-80.13285065	Fixed	0.16
464	Elliott Key Daybeacon 19	25.39251328	-80.1829834	Fixed	0.16
465	Key Largo Daybeacon 29	25.237957	-80.2834549	Fixed	0.16
466	Largo Sound Channel Light 9	25.09989929	-80.4126358	Fixed	0.16
467	Boca Chica Light 56	24.55218315	-81.68680573	Fixed	0.16
468	Largo Sound Channel Daybeacon 6A	25.09989166	-80.41114044	Fixed	0.16
469	Largo Sound Channel Daybeacon 7A	25.09988403	-80.41104889	Fixed	0.16
470	Fort Jefferson West Channel Daybeacon 6	24.62457085	-82.87832642	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
471	Stevens Cay Light	18.33179474	-64.80859375	Fixed	0.16
472	Fowey Rocks Daybeacon 3	25.59486198	-80.11582184	Fixed	0.16
473	Fort Jefferson East Channel Daybeacon 6	24.63341904	-82.87257385	Fixed	0.16
474	Largo Sound Channel Daybeacon 23	25.1265564	-80.39748383	Fixed	0.16
475	Ofu Harbor Light 1	-14.16353321	-169.6808472	Fixed	0.16
476	Tavernier Key Daybeacon 3	25.00197029	-80.49045563	Fixed	0.16
477	Old Rhodes Key Daybeacon 23	25.33594131	-80.20942688	Fixed	0.16
478	Fort Jefferson West Channel Daybeacon 12	24.62451363	-82.87329102	Fixed	0.16
479	Elliott Key Daybeacon 17	25.43405914	-80.16516876	Fixed	0.16
480	Big Pine Shoal Light 22	24.56835556	-81.32565308	Fixed	0.16
481	Old Rhodes Key Daybeacon 21	25.35671425	-80.19538879	Fixed	0.16
482	Miami Main Channel Entrance Range Rear Light	25.74979401	-80.13312531	Fixed	0.16
483	Kaneohe Bay Channel Light 21	21.45356941	-157.8036499	Fixed	0.16
484	Bache Shoal Daybeacon 9	25.49651718	-80.14408875	Fixed	0.16
485	Kawaihae Harbor South Breakwater Light 8	20.03461266	-155.833786	Fixed	0.16
486	Kaneohe Bay Entrance Range Rear Light	21.49256325	-157.8364716	Fixed	0.16
487	Sampan Channel Range Front Light	21.43478584	-157.8050537	Fixed	0.16
488	Angelfish Creek Light 2	25.32844162	-80.25019836	Fixed	0.16
489	Kaneohe Bay Channel Daybeacon 11	21.48821449	-157.8301544	Fixed	0.16
490	Snake Creek Daybeacon 6A	24.9455719	-80.58305359	Fixed	0.16
491	Pirates Cove Daybeacon 5	24.61853981	-81.5091095	Fixed	0.16
492	Hillsboro Inlet Entrance Daybeacon 5	26.25639153	-80.08081818	Fixed	0.16
493	Hillsboro Inlet Entrance Shl Daybeacon	26.25638962	-80.08055878	Fixed	0.16
494	Hillsboro Inlet Entrance Light 2	26.25638962	-80.07887268	Fixed	0.16
495	Snake Creek Daybeacon 1	24.94111443	-80.5811615	Fixed	0.16
496	Soldier Key Daybeacon 2	25.59622383	-80.12594604	Fixed	0.16
497	Elliott Key Daybeacon 15	25.45777893	-80.16160583	Fixed	0.16
498	Snake Creek Daybeacon 6	24.94405746	-80.58338928	Fixed	0.16
499	Hickam Harbor Channel Light 2	21.30337334	-157.9521637	Fixed	0.16
500	Largo Sound Channel Daybeacon 17	25.11752701	-80.40206146	Fixed	0.16
501	Christiansted Harbor Channel Light 10	17.75736046	-64.70029449	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
502	Snake Creek Daybeacon 8	24.94849396	-80.58588409	Fixed	0.16
503	Key Largo Light 32	25.1768856	-80.33943939	Fixed	0.16
504	Boca Chica Channel Daybeacon 3	24.55053139	-81.72412872	Fixed	0.16
505	Mosquito Bank Light 35	25.07300949	-80.3928299	Fixed	0.16
506	Biscayne Channel Daybeacon 7	25.65280533	-80.15167999	Fixed	0.16
507	Middle Sambos Shoal Daybeacon	24.4884758	-81.67743683	Fixed	0.16
508	Angelfish Creek Daybeacon 8	25.33429527	-80.25525665	Fixed	0.16
509	Dry Tortugas Southwest Channel Daybeacon 6	24.63175583	-82.88561249	Fixed	0.16
510	Largo Sound Channel Daybeacon 22	25.12638092	-80.39732361	Fixed	0.16
511	Port Everglades Spoil Bank East Daybeacon	26.09765625	-80.10030365	Fixed	0.16
512	Key Largo Daybeacon 27	25.26592255	-80.26099396	Fixed	0.16
513	Angelfish Creek Daybeacon 2A	25.32979774	-80.2514801	Fixed	0.16
514	Kalihi Channel Range Front Light	21.30905151	-157.8952942	Fixed	0.16
515	Key Largo Light 25	25.28668022	-80.24465179	Fixed	0.16
516	Heeia Kea Small Boat Harbor Daybeacon 1	21.44618034	-157.808075	Fixed	0.16
517	Dry Tortugas Southeast Channel Daybeacon 4	24.64499283	-82.85473633	Fixed	0.16
518	Snake Creek Daybeacon 9	24.94837761	-80.58677673	Fixed	0.16
519	Whale Harbor Channel Daybeacon 3	24.9320755	-80.59668732	Fixed	0.16
520	Hillsboro Inlet Entrance Light 1	26.25471878	-80.07969666	Fixed	0.16
521	Channel Five Daybeacon 1	24.81803322	-80.77880859	Fixed	0.16
522	Ofu Harbor Light 2	-14.16377735	-169.682785	Fixed	0.16
523	Fort Jefferson East Channel Daybeacon 2	24.63609695	-82.87499237	Fixed	0.16
524	Turtle Harbor Daybeacon 4	25.27772713	-80.22315979	Fixed	0.16
525	Fort Jefferson West Channel Daybeacon 10	24.62426949	-82.87422943	Fixed	0.16
526	Pelican Shoal Light 26	24.50608444	-81.59973907	Fixed	0.16
527	Port Everglades Light 4	26.09456444	-80.10216522	Fixed	0.16
528	Angelfish Creek Daybeacon 1	25.32823944	-80.2503891	Fixed	0.16
529	Kaneohe Bay Channel Danger Light	21.44902039	-157.7957916	Fixed	0.16
530	Snake Creek Daybeacon 5	24.94240952	-80.58318329	Fixed	0.16
531	Largo Sound Channel Daybeacon 5	25.09807777	-80.40457916	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
532	Ceasar Creek Dbn 13	25.38323402	-80.21798706	Fixed	0.16
533	Turtle Harbor Daybeacon 3	25.2806797	-80.21445465	Fixed	0.16
534	Fort Jefferson West Channel Daybeacon 2	24.62868309	-82.8817749	Fixed	0.16
535	Snake Creek Daybeacon 4	24.94240379	-80.58280945	Fixed	0.16
536	Tavernier Creek Light	24.98686028	-80.52278137	Fixed	0.16
537	Largo Sound Channel Daybeacon 4	25.09807205	-80.40458679	Fixed	0.16
538	Barbers Point Harbor Entrance Channel Light 6	21.32196617	-158.1211395	Fixed	0.16
539	Elliott Key Daybeacon 18	25.42337227	-80.17939758	Fixed	0.16
540	Tavernier Key Daybeacon 4	25.00462532	-80.50726318	Fixed	0.16
541	Biscayne Channel Light 3	25.65112877	-80.14440918	Fixed	0.16
542	Sister Creek Daybeacon 4	24.68924904	-81.0874176	Fixed	0.16
543	Christiansted Harbor Channel Daybeacon 16	17.74726486	-64.70118713	Fixed	0.16
544	Sand Key Light (Abandoned)	24.45581627	-81.87731171	Fixed	0.16
545	Largo Sound Channel Daybeacon 11	25.10097122	-80.41321564	Fixed	0.16
546	Bahia De Guayanilla Range Front Passing Light	17.9769001	-66.76383972	Fixed	0.16
547	Largo Sound Channel Daybeacon 12	25.10392761	-80.41431427	Fixed	0.16
548	Hickam Harbor Channel Light 6	21.31033325	-157.9532928	Fixed	0.16
549	Fort Jefferson West Channel Daybeacon 4	24.62563133	-82.87973785	Fixed	0.16
550	Turtle Harbor West Shoal Preferred Channel Light	25.30434608	-80.21396637	Fixed	0.16
551	Boca Chica Channel Daybeacon 6	24.55764771	-81.72003937	Fixed	0.16
552	Snake Creek Daybeacon 7	24.94524384	-80.58369446	Fixed	0.16
553	Ragged Key Daybeacon 7	25.5170002	-80.13784027	Fixed	0.16
554	East Turtle Shoal Light 45	24.72465897	-80.93305206	Fixed	0.16
555	Barbers Point Harbor Entrance Channel Light 5	21.32039452	-158.1252747	Fixed	0.16
556	Barbers Point Harbor Entrance Channel Light 7	21.32328033	-158.1221771	Fixed	0.16
557	American Shoal Light	24.52511787	-81.51941681	Fixed	0.16
558	Fort Jefferson West Channel Daybeacon 8	24.62410164	-82.87660217	Fixed	0.16
559	Channel Five Light 2	24.81488991	-80.77455139	Fixed	0.16
560	Waianae Harbor Breakwater Light 1	21.44741249	-158.1969147	Fixed	0.16
561	Safe Harbor Channel Light 4	24.55168915	-81.73316193	Fixed	0.16
562	Bird Key Harbor Daybeacon 3BK	24.62408257	-82.8806076	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
563	Dry Tortugas Southwest Channel Daybeacon 3	24.62703705	-82.90833282	Fixed	0.16
564	Old Rhodes Key Daybeacon 24	25.33547783	-80.21624756	Fixed	0.16
565	Alligator Reef Daybeacon 43	24.86222839	-80.63852692	Fixed	0.16
566	Largo Sound Channel Daybeacon 16	25.11568451	-80.40274048	Fixed	0.16
567	Las Croabas Daybeacon 3	18.36389542	-65.62316132	Fixed	0.16
568	East Washerwoman Shoal Light 49	24.66690826	-81.07279968	Fixed	0.16
569	Angelfish Creek Light 6	25.33247566	-80.2539444	Fixed	0.16
570	Molasses Reef Light 10	25.01184845	-80.37647247	Fixed	0.16
571	Western Sambos North Shoal Daybeacon	24.48665619	-81.70833588	Fixed	0.16
572	Whale Harbor Daybeacon 2	24.93181419	-80.59568024	Fixed	0.16
573	Fort Jefferson West Channel Daybeacon 7	24.62550545	-82.87686157	Fixed	0.16
574	Teatable Key Daybeacon 42	24.87700081	-80.6533432	Fixed	0.16
575	Pirates Cove Daybeacon 2	24.60774994	-81.51111603	Fixed	0.16
576	Honolulu Harbor Entrance Light	21.29575348	-157.8690033	Fixed	0.16
577	Coffins Patch Light 20	24.67573166	-80.95748138	Fixed	0.16
578	Loggerhead Key Light 50A	24.59738731	-81.45475769	Fixed	0.16
579	Alligator Reef Light	24.85178757	-80.61885071	Fixed	0.16
580	Biscayne Channel Light 6	25.65386963	-80.14962006	Fixed	0.16
581	Whale Harbor Channel Daybeacon 7	24.93768311	-80.60804749	Fixed	0.16
582	Fort Jefferson West Channel Daybeacon 11	24.6254425	-82.87355804	Fixed	0.16
583	Upper Matecumbe Daybeacon 41	24.88878822	-80.60416412	Fixed	0.16
584	Mayaguez Harbor Daybeacon	18.20800018	-67.15797424	Fixed	0.16
585	Dry Tortugas Southeast Channel Light 3	24.63873482	-82.86134338	Fixed	0.16
586	Pirates Cove Daybeacon 7	24.62098885	-81.50997162	Fixed	0.16
587	Kaneohe Bay Channel Daybeacon 5	21.49926949	-157.8269501	Fixed	0.16
588	Turtle Harbor Daybeacon 5	25.26996422	-80.2207489	Fixed	0.16
589	Bahia De Guayanilla Entrance Range Front Light	17.97689819	-66.76383972	Fixed	0.16

Appendix C-3

USCG ATON with Impact Areas Intersecting Coral Reefs in Descending Order of Impact Area

Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
1	Ala Wai Boat Harbor Entrance Lighted Buoy 2	21.27614212	-157.8461456	Floating	9,273.41
2	Miami Main Channel Lighted Buoy 3	25.76107216	-80.09693146	Floating	3,403.89
3	Tinian Harbor Channel Lighted Buoy 2	14.95670986	145.6227417	Floating	3,166.18
4	Fort Jefferson Buoy N	24.63743973	-82.78659058	Floating	3,011.79
5	Kewalo Basin Lighted Buoy 2	21.2875309	-157.8621216	Floating	2,698.48
6	Fort Jefferson Buoy G	24.69444466	-82.92221832	Floating	2,394.85
7	Dixie Shoal Buoy 8	25.07765579	-80.31197357	Floating	2,329.20
8	Miami Main Channel Lighted Buoy 1	25.76315498	-80.08990479	Floating	2,315.67
9	Midway Channel Entrance Lighted Buoy 1	28.19831848	-177.3559723	Floating	2,315.67
10	Dry Tortugas Southeast Channel Lighted Buoy 2	24.62319946	-82.82945251	Floating	2,216.97
11	Tanapag Harbor Channel Lighted Buoy 2	15.22020626	145.6902466	Floating	2,166.38
12	Bajo Amarillo Lighted Buoy 2	18.27776909	-65.27521515	Floating	2,094.67
13	Miami Anchorage Buoy A	25.80574989	-80.09514618	Floating	2,039.00
14	Pearl Harbor Entrance Lighted Buoy 2	21.29916573	-157.9546661	Floating	1,871.36
15	Ko'Olina CG Mooring Buoy	21.33933258	-158.1371613	Floating	1,833.07
16	Fort Jefferson Buoy B	24.56665611	-82.93335724	Floating	1,802.35
17	Rebecca Shoal Lighted Buoy 4	24.57877922	-82.59075165	Floating	1,779.05
18	Coalbin Rock Buoy CB	24.45097733	-82.08826447	Floating	1,745.47
19	Fort Jefferson Lighted Buoy K	24.72553444	-82.79997253	Floating	1,729.58
20	Kalihi Channel Lighted Buoy 3	21.29419899	-157.8977814	Floating	1,692.66
21	Kalihi Channel Lighted Buoy 4	21.29408646	-157.8965912	Floating	1,692.66
22	Honolulu Harbor Channel Lighted Buoy 1	21.29166985	-157.8740845	Floating	1,689.06
23	Bajo Grouper Buoy 5	18.2849617	-65.26642609	Floating	1,558.89
24	Ala Wai Boat Harbor Entrance Lighted Buoy 1	21.27625465	-157.8469849	Floating	1,523.55
25	St Thomas Harbor Entrance Lighted Buoy 2	18.30958176	-64.91786957	Floating	1,522.11
26	Honolulu Harbor Channel Lighted Buoy 6	21.29559708	-157.8701019	Floating	1,519.52
27	Canal Del Este Buoy 2	18.27679062	-65.2516098	Floating	1,481.67
28	Fort Jefferson Buoy D	24.60833359	-82.96666718	Floating	1,413.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
29	Dry Tortugas Southwest Channel Buoy 1	24.61126328	-82.92734528	Floating	1,399.65
30	Kalihi Channel Entrance Lighted Buoy 1	21.28981018	-157.8985443	Floating	1,392.52
31	Punta Colorada Lighted Buoy 9	18.29315376	-65.27635193	Floating	1,391.87
32	Pearl Harbor Entrance Lighted Buoy 1	21.29783821	-157.956955	Floating	1,316.23
33	Crocker Reef Buoy 16	24.90826988	-80.52453613	Floating	1,284.23
34	Tinian Harbor Channel Lighted Buoy 4	14.95910454	145.6243134	Floating	1,239.00
35	Lake Worth Lighted Buoy LW	26.77266121	-80.01006317	Floating	1,147.85
36	Honolulu Harbor Channel Lighted Buoy 2	21.29097557	-157.8726654	Floating	1,124.59
37	Tanapag Harbor Approach Lighted Buoy T	15.20319366	145.6746979	Floating	1,086.77
38	Taema Bank Lighted Buoy 1	-14.32387638	-170.6745758	Floating	1,053.28
39	Kalihi Channel Lighted Buoy 6	21.29919434	-157.8959351	Floating	1,021.31
40	Packet Rock Buoy 2	18.29662895	-64.88986969	Floating	960.01
41	Midway Channel Buoy 3	28.20252228	-177.3552551	Floating	956.60
42	Kahului Harbor Lighted Buoy 6	20.89698601	-156.4747314	Floating	915.28
43	Honolulu Harbor Channel Lighted Buoy 5	21.29764175	-157.8706512	Floating	887.85
44	Midway Channel Entrance Buoy 2	28.19833755	-177.3532867	Floating	822.42
45	Midway Channel Buoy 4	28.2023735	-177.3539429	Floating	791.73
46	Honolulu Harbor Channel Buoy 3	21.29508591	-157.8721771	Floating	651.61
47	Kewalo Basin Lighted Buoy 1	21.28782272	-157.8625946	Floating	624.32
48	KAILUA BAY SECURITY ZONE BUOY	21.42194366	-157.7416687	Floating	591.02
49	Tinian Harbor Channel Lighted Buoy 1	14.95392704	145.6233368	Floating	496.92
50	Kalihi Channel Lighted Buoy 5	21.2994957	-157.8970032	Floating	447.45
51	Barbers Point Harbor Entrance Channel Lighted Buoy 2	21.31538963	-158.1279602	Floating	378.13
52	Bajo Camaron Buoy 6	18.2856102	-65.26316071	Floating	377.17
53	Kewalo Basin Lighted Buoy 3	21.28981209	-157.8611603	Floating	285.03
54	Hickam Harbor Channel Buoy 1	21.30352211	-157.9530182	Floating	285.02
55	Looe Key Light 24 target position	24.54680252	-81.40258026	Floating	280.48
56	Key West Main Channel Lighted Buoy 3	24.47005844	-81.80204773	Floating	263.11
57	Honolulu Harbor Channel Buoy 4	21.29432869	-157.8708801	Floating	232.92

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
58	Kewalo Basin Lighted Buoy 4	21.28980064	-157.8604584	Floating	201.11
59	Diamond Head Reef Lighted Buoy 2	21.24683762	-157.8156586	Floating	180.66
60	Bajo Snapper Lighted Buoy 8	18.28935814	-65.27153015	Floating	165.45
61	Midway Channel Buoy 8	28.20991135	-177.3540649	Floating	135.94
62	Tinian Harbor Channel Buoy 6	14.96194649	145.6230621	Floating	121.52
63	Apra Outer Harbor Lighted Buoy 5	13.45359135	144.6560211	Floating	102.95
64	Hickam Harbor Channel Buoy 5	21.30971909	-157.9536133	Floating	85.18
65	Apra Harbor Western Shoal Buoy WS	13.44988346	144.6539154	Floating	81.91
66	Miami Main Channel Lighted Buoy 2	25.76251602	-80.09754181	Floating	70.56
67	Bahia De Tallaboa Lighted Buoy 4	17.96554756	-66.73674774	Floating	25.89
68	Christiansted Harbor Channel Light 9	17.75631142	-64.69843292	Fixed	0.82
69	Christiansted Harbor Channel Light 11	17.75563049	-64.69910431	Fixed	0.82
70	New Ground Rocks Light	24.66659927	-82.44416046	Fixed	0.66
71	Dry Tortugas Southeast Channel Light 1	24.59363937	-82.87374115	Fixed	0.66
72	Kaneohe Bay Channel Lighted Buoy 2	21.51459885	-157.8111115	Floating	0.55
73	Kalihi Channel Light 7	21.30479813	-157.8964996	Fixed	0.49
74	Kalihi Channel Light 8	21.30450058	-157.8951416	Fixed	0.49
75	Maunalua Bay Light 1	21.27086258	-157.7155914	Fixed	0.49
76	Kalihi Channel Light 10	21.30814743	-157.8936768	Fixed	0.49
77	Las Croabas Daybeacon 2	18.36378479	-65.62216187	Fixed	0.16
78	Barbers Point Harbor Entrance Channel Light 4	21.31876373	-158.1245728	Fixed	0.16
79	Kaneohe Bay Channel Daybeacon 15	21.47034836	-157.8261719	Fixed	0.16
80	Pacific Reef Light	25.37098503	-80.14205933	Fixed	0.16
81	Stock Island Approach Channel Light 32	24.47470856	-81.74214935	Fixed	0.16
82	Pulaski Shoal Light	24.69333839	-82.772995	Fixed	0.16
83	Fort Jefferson West Channel Daybeacon 9	24.62532806	-82.87550354	Fixed	0.16
84	Hickam Harbor Channel Daybeacon 3	21.30711365	-157.9529877	Fixed	0.16
85	Fort Jefferson East Channel Daybeacon 7	24.63267708	-82.8707428	Fixed	0.16
86	Dry Tortugas Southeast Middle Ground Daybeacon	24.64741707	-82.8706665	Fixed	0.16
87	Fort Jefferson East Channel Daybeacon 5	24.63410378	-82.87152863	Fixed	0.16

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Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
88	Kaneohe Bay Channel Light 14	21.47308731	-157.8289795	Fixed	0.16
89	Hickam Harbor Channel Daybeacon 4	21.30705833	-157.9520721	Fixed	0.16
90	Bird Key Harbor Daybeacon 2BK	24.62521553	-82.88147736	Fixed	0.16
91	Looe Key Light 24	24.54680252	-81.40258026	Fixed	0.16
92	Dry Tortugas Southwest Channel Daybeacon 4	24.62805939	-82.89810181	Fixed	0.16
93	Fort Jefferson East Channel Daybeacon 3	24.63544846	-82.87258911	Fixed	0.16
94	Kaneohe Bay Channel Daybeacon 12	21.48739815	-157.8325348	Fixed	0.16
95	Western Dry Rocks Daybeacon K	24.44638824	-81.92683411	Fixed	0.16
96	Fort Jefferson West Channel Daybeacon 3	24.62804222	-82.87981415	Fixed	0.16
97	Pacific Reef Daybeacon 3	25.37365723	-80.15983582	Fixed	0.16
98	Government Cut Range Rear Light	25.75035858	-80.10148621	Fixed	0.16
99	Kaneohe Bay Utility Channel Daybeacon 3	21.45267296	-157.782486	Fixed	0.16
100	Hillsboro Inlet Daybeacon 3	26.25543213	-80.08011627	Fixed	0.16
101	Western Sambos Shoal Daybeacon	24.48311996	-81.70310211	Fixed	0.16
102	Turtle Harbor Daybeacon 6	25.27241898	-80.22795105	Fixed	0.16
103	Eastern Sambos Shoal Daybeacon	24.49189758	-81.66343689	Fixed	0.16
104	Rebecca Shoal Light (Abandoned)	24.57902336	-82.58521271	Fixed	0.16
105	Bird Key Harbor Daybeacon 5BK	24.62037468	-82.87974548	Fixed	0.16
106	Cosgrove Shoal Light	24.457901	-82.18504333	Fixed	0.16
107	Western Sambos West Shoal Daybeacon	24.48003387	-81.7193985	Fixed	0.16
108	Fowey Rocks Light	25.59062386	-80.09673309	Fixed	0.16
109	Kaneohe Bay Channel Light 18	21.46102524	-157.8218689	Fixed	0.16
110	White Shoal North Daybeacon 7	24.64835739	-82.89295959	Fixed	0.16
111	Pearl Harbor Light 5	21.31516457	-157.96698	Fixed	0.16
112	Middle Ground Daybeacon 3	24.48286057	-81.88149261	Fixed	0.16
113	Big Pine Shoal Light 22	24.56835556	-81.32565308	Fixed	0.16
114	Kaneohe Bay Channel Light 21	21.45356941	-157.8036499	Fixed	0.16
115	Sampan Channel Range Front Light	21.43478584	-157.8050537	Fixed	0.16
116	Hillsboro Inlet Entrance Daybeacon 5	26.25639153	-80.08081818	Fixed	0.16

Appendix C-3

Number	Name	Latitude	Longitude	ATON Type	Impact Area (m2)
117	Hillsboro Inlet Entrance Shl Daybeacon	26.25638962	-80.08055878	Fixed	0.16
118	Hickam Harbor Channel Light 2	21.30337334	-157.9521637	Fixed	0.16
119	Middle Sambos Shoal Daybeacon	24.4884758	-81.67743683	Fixed	0.16
120	Dry Tortugas Southwest Channel Daybeacon 6	24.63175583	-82.88561249	Fixed	0.16
121	Heeia Kea Small Boat Harbor Daybeacon 1	21.44618034	-157.808075	Fixed	0.16
122	Dry Tortugas Southeast Channel Daybeacon 4	24.64499283	-82.85473633	Fixed	0.16
123	Fort Jefferson East Channel Daybeacon 2	24.63609695	-82.87499237	Fixed	0.16
124	Pelican Shoal Light 26	24.50608444	-81.59973907	Fixed	0.16
125	Kaneohe Bay Channel Danger Light	21.44902039	-157.7957916	Fixed	0.16
126	Fort Jefferson West Channel Daybeacon 2	24.62868309	-82.8817749	Fixed	0.16
127	Hickam Harbor Channel Light 6	21.31033325	-157.9532928	Fixed	0.16
128	Fort Jefferson West Channel Daybeacon 4	24.62563133	-82.87973785	Fixed	0.16
129	Barbers Point Harbor Entrance Channel Light 5	21.32039452	-158.1252747	Fixed	0.16
130	Waianae Harbor Breakwater Light 1	21.44741249	-158.1969147	Fixed	0.16
131	Bird Key Harbor Daybeacon 3BK	24.62408257	-82.8806076	Fixed	0.16
132	Dry Tortugas Southwest Channel Daybeacon 3	24.62703705	-82.90833282	Fixed	0.16
133	East Washerwoman Shoal Light 49	24.66690826	-81.07279968	Fixed	0.16
134	Fort Jefferson West Channel Daybeacon 7	24.62550545	-82.87686157	Fixed	0.16
135	Honolulu Harbor Entrance Light	21.29575348	-157.8690033	Fixed	0.16
136	Dry Tortugas Southeast Channel Light 3	24.63873482	-82.86134338	Fixed	0.16
137	Port Everglades Light 5	26.09261513	-80.1023941	Fixed	0.12
138	Sombrero Key Light	24.62784386	-81.11080933	Fixed	0.09